Low Cost Laboratory Plant for Control Systems

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***ABSTRACT*: This article deals with the design of low cost plants in the laboratory. It is ideal for teaching cybernetics and the systems of power. Through its use it is possible to further improve the students 'knowledge and skills, in particular encouraging them to engage in practical exercises, thus increasing their ability to memorize learned knowledge. When these laboratory plants were introduced into classrooms, there was an increase in the interest of the students in this subject and their positive response. This article deals with the learning habits of the students present in the class. It is ideal for teaching automations and the systems of power. Through its use it is possible to further improve the students 'knowledge and skills, in particular encouraging them to engage in practical exercises, thus increasing their ability to memorize learned knowledge. When these laboratory plants were introduced into classrooms, there was an increase in the interest of the students in this subject and their positive response.**

***KEYWORDS*: Embedded Systems, Microprocessors and Microcontrollers; Control System Education; Arduino; DC Motor, REX Control System.**

INTRODUCTION

Constantly developing and elaborating on the topic of power. For this trend to continue, more people need to be educated on the topic. This is important to educate and communicate knowledge and observations so that various methods can be applied, otherwise their exploration will be in vain. The use of concrete examples and assignments is a positive practice which can be used in classroom. Generally speaking, students who become acquainted with the subject in a realistic way and attempt to solve the problem in a laboratory have a propensity to memorize, and most importantly understand, the question. In strictly theoretical lesson, they can then easily apprehend more relationships or problems that they would not be able to foresee and link with action. It is therefore best to use realistic examples and laboratory plants (in lessons that require this) with which students can work independently and bring the results of the lesson into effect. The fact that a simple inverted pendulum is one of the most commonly used models, speaks for itself. This method is fairly complex and requires the carrying out of several tasks.

But it is important to continue with something simpler in the basic lessons of cybernetics and control systems. The most basic is a comprehension of the theory and functionality of a simple control loop using negative feedback. For this purpose, various basic systems may be used-the RC circuit and its charging, temperature control, or DC motor speed control. The first case is a device which if more parts are linked becomes a higher order. Its explanation is easy to extract, and easy to manage, too. However, the downside is its distance from reality, firstly because it is not an example of a real world, secondly because of a certain invisibility of the meaning of power. To make the voltage clear, you will use another tool to test the voltage. Unit dynamics can be chosen by combining the importance of resistance and efficiency over a long interval. Time constants can range from milliseconds to seconds to minutes or even.

The second example focuses more on the normal practice in households or in industry. Building suitable laboratory farm, though, is complicated. Although temperature measurement with simple sensors is easy to do, understanding of the manipulated value is more complicated. The case of positive values is called heating, which can be achieved with a resistance tube, a light bulb etc. Negative variable values are not so easily manipulated [1]. It is possible to use a ventilator; however, the final device will have different properties with respect to the changing polarity of the controlled value, and would be highly affected by the environment. Dynamics would rely on the overall design of the system but improvements would be fairly slow (ten seconds or minutes more likely).

The last example is also realistic task-oriented. In some types of equipment and other devices or in industry, which uses manipulators etc., motor speed control is found. The function itself is important because changes in rotation speed are easily noticeable and interference in the form of a shaft brake is easy to apply. By generating PWM signal from the digital control system and using H-bridge, measuring the output value can be achieved using various sensors which are not complicated and can be controlled [2]. Dynamics is determined by the load attached to the engine shaft and by the characteristics of the motor. And the transfer time constant is in tens or hundreds of milliseconds.

The last version of systems offered was selected as suitable. The most benefits are machine applying DC motor. To build the control system, the Arduino platform (version-Uno) was chosen. It is one of the most widely used and well-known 8-bit microcontroller based platform. There are numerous examples of working with this platform which makes students easy to research on their own. The main was the simplicity of control algorithm design and open-source development environment with many functions, in addition to vast support. Therefore, students are not expected to familiarize themselves with complex programming language or any platform, leaving the key focus to be the problem of designing the control system, which is very easy to implement on a particular platform.

LITERAURE REVIEW

This paper present a cost efficient approach to remote experimentation proposing ArPi Lab-remote laboratory for process control training. This lab is focused on very inexpensive hardware components like Raspberry Pi single-board computers and Arduino open prototyping platforms based on 8-bit microcontrollers. This method is a blend of different software technologies. These are HTML 5 and JavaScript for client-side use, PHP and MySQL for lab server implementation, JSON as data transfer structure and C language for server experiment and microcontroller programming. ArPi Lab offers three distinct types of physical education programs. For remote laboratory experiments three thermal plants, one magnetic levitation, and one hydraulic tank system are available [1]. This paper presents low-cost laboratories which aim to improve electrical and electronic engineering teaching. The laboratories were designed and developed based on the Raspberry Pi microprocessor system and aim to introduce students to the incorporation of software and hardware into electrical engineering as well as to ensure that students understand the theoretical foundations of areas such as digital signal processing and instrumentation. The paper describes the activities which were produced in the laboratory. Feedback was obtained from the students and analyzed [2]. The lack of adequate resources and manpower for the procurement and maintenance of laboratory equipment, primarily due to the recent economic crisis, has led us to a drastic reform of the functional laboratory courses, which are now based on cheap take-home kits, fitted with Arduino-based electronics and compatible sensors. There is no question that low-cost take-home equipment will increase the student's interest in theory and practice of training, enabling them to study in their own place and at any convenient time.

Within this paper a model for monitoring the instruments and experiments using a low cost control architecture in a remote laboratory. This model is based on interchangeable drivers on a LAN network, and a control methodology. The goal is to obtain a software control architecture independent of the laboratory's hardware, so that each organization can implement its own solution according to the devices available and with minimal restrictions on the laboratory's hardware[3]. The paper describes how to build and deploy a low-cost platform for remote experiment control via webpage and a Microchip PIC microcontroller. Thus we have an easily implemented tool to improve learning by plug-and-play process and probably cover many types of students and institutions [3]. This article deals with the design and construction of low cost laboratory facilities for the education of control systems. The system requires DC motor with quadratic incremental encoder. Digital control system is realized using the Arduino platform. Raspberry Pi can also be used to communicate with laboratory plant and REX Control System to develop control algorithms.

Within this work presents an architecture which has been introduced for control systems remote laboratories. The software is implemented within the University in a laboratory, and it only requires a local computer connected to the physical network in which the student can operate remotely. All solution is free software oriented, removing the need to buy costly licenses. In the paper, author explain the software implementation, and present the contrast between the effects of on-site and remotely testing with the physical structures to validate the method. This paper introduces a web-based, low-cost virtual laboratory workbench for use as part of electronic engineering undergraduate training courses. Some of the distinguishing features of the virtual workbench are that students are able to carry out curriculum-based laboratory tasks in a practical manner; it incorporates a Bayesian Network-based evaluation framework for student performance assessment; and it allows the professor versatility in designing laboratory practice. The laboratory portion of undergraduate engineering education presents challenges in resource-restricted faculties of engineering [4]. This paper presents low- laboratories which aim to improve electrical and electronic engineering teaching. The laboratories were designed and developed based on the Raspberry Pi microprocessor system and aim to introduce students to the incorporation of software and hardware into electrical engineering as well as to ensure that students understand the theoretical foundations of areas such as digital signal processing and instrumentation. The paper describes the activities which were produced in the laboratory.

Feedback was obtained from the students and analyzed. The positive response shows this approach's efficacy in teaching electrical and electronic engineering [5]. This study aimed to demonstrate a new low-cost and compact laboratory kit concept that is prospective to help teaching and learning on the automation cycle. The package consists of a water tank filling system fitted with an integrated programmable logic controller (PLC) with SCADA system, human machine interface (HMI) display, reservoir, temperature, water level sensor, mixer, and heater. The kit was put on the portable table to be adaptable to every sort of classroom. The tank was designed to be mixed and connected to other tanks for approaching the industrial tank system in industry, and the volumetric temperature and water (water level) was controllable. There are also many obstacles to introducing a hands-on environment in distance learning courses. For courses such as circuits, circuitry, embedded systems, many inexpensive and useful home laboratory kits are available but some introductory courses remain out of reach. In this paper, author describe a low-cost, turnkey laboratory control system package that is inexpensive, safe and versatile enough to meet the demands of a course of college level controls. This laboratory kit combines a DC motor, a sensor, a microcontroller and a USB interface in an integrated home-use device. The embedded firmware in the kit enables the student to define the kit's motor, build a PID control loop, and construct loop response Bode plots [6].

METHOD

The laboratory plant should be used on different subjects. First is the shield board that is compatible with the Arduino Uno and Mega platform and includes basic user interface, simple RC circuit based systems and motor board connectors. This second board is the basis of the later mentioned control system used to do the example of controller design.

Shield board

The principal feature of the concept was the basic part's simplicity. Nevertheless, at the same time, emphasis was put on the possibility of extensions; hence, shield can be used as an interface for controlling certain more complex systems. Separating these more complicated pieces from the basic model has the benefit of reducing its price while also retaining the prospect of further expansion. The board parts are modified in such a way that the students can become familiar with basics of regulating simple processes and calculating output values and implemented two serially connected RC circuits, as an example of a simple dynamic network. The input of this method is realized by PWM signal, the length of which is less than the method time constants. At the point of view of the output signal, the device then behaves as if its input represented a continuous analog signal that corresponds to the function of the PWM excitation signal. The feature benefit is the ability to calculate the performance value from both the first and second RC circuits. Therefore students will slowly become acquainted with the issue of first and second order controlling systems. The framework can also be used for teaching cascade control systems to track the signal located "inside".

To complement the problem of regulating a second, the same method is used with RC circuits. However, excitement of this device is associated using LED and photosensitive resistor. Thanks to this relation, in the form of a local illumination or partial blockage of the light beam between LED and photosensitive resistor, a disruption signal is brought into the network. It helps students to test what effect it disruption signal has on the control quality inside the closed loop control system. Extra attention has been given to implementing this component, especially in terms of adjusting the signal that comes from a photosensitive resistor. Therefore, outputs of both RC circuit systems are very similar when the signal of malfunction is ignored. Through comparing outputs of the same control circuit, we can see the disturbance signal's effect on the output value.

Other elements are attached to the board to familiarize with the possibilities of contact with the user-controlled systems and the calculation of process quantities. There are two LEDs to indicate the condition, one connected only to the digital output, the other allowing control of the brightness via PWM signal. The entire board was planned as an additional shield for Arduino, thus keeping in mind not to increase the size of the entire platform unnecessarily. From an electrical point of view, individual parts of this board are connected so that full use of Arduino platform microcontroller hardware peripherals is done. So a timer is used to generate all PWM signals. Analog values can be calculated thanks to an integrated A/D converter, and the external interrupts can be used to read user input and count pulses from the encoder. Both of these steps lower the computation requirements that would be needed to implement such functions in software. Thus the interface enables simple 8bit microcontroller to be used even for fairly complex tasks.

Fig. 1. Shield board for Arduino

Motor board

This is a shield board extension that enables the motor rotation control operation. While this is one of the basic tasks in automation, the need for accurate motor shaft positioning and an exact motor speed profile that increase the complexity of this task. The shield board makes attachment to virtually any electromotor, but for this extension design the simplest form of them was chosen – brushed DC motor with permanent magnets. The choice of motor power has also been very conservative, as the product is intended to demonstrate and design control algorithms and does not actually operate on anything, hence there is no need to use high-power one. The final option was a small carbon-brushes engine. Therefore, the laboratory plant does not need external power supply, as ample power is supplied from a computer's USB port through the development platform Arduino. The carbon brushes provide durability for the engine.

From an electronic point of view, the platform implements H-bridge which converts digital signals about rotation direction and PWM signal with motor power information to power signals that are suitable for motor excitation. In this paper magnetic incremental quadrature encoder is chosen that uses diametrically magnetized cylinder-shaped magnet connected to the motor shaft to determine the rotation velocity and shaft position. Within the magnetic encoder, the location of this magnet is evaluated, based on a signal from the array of hall sensors. If the position of the magnet changes, the sensor generates pulses which correspond to the change. To mount the magnet to the motor shaft, it was specifically for this purpose that a special component was designed and printed on the 3D printer. The component also helps to mount the load in the form of an M8 nut, which increases the system's time constant. The last section of the platform is the circuit where the current is measured through the motor. This current correlates to the motor torque and the ability to calculate it opens up possibilities for more complex and precise control algorithms being introduced.

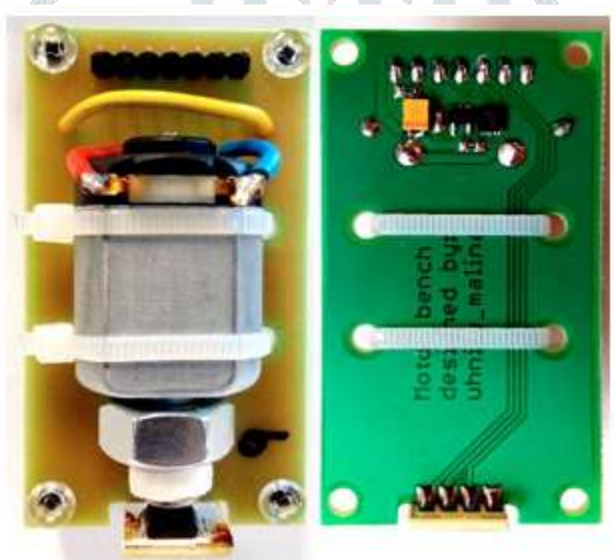

Fig. 2. Motor board with H-bridge and current sensor

CONCLUSION

This article deals with the construction of low cost plants in the laboratory. This is ideal for teaching cybernetics and the systems of power. With its use it is possible to further improve the students 'knowledge and skills, in particular encouraging them to engage in practical exercises, thus increasing their ability to memorize learned knowledge. When these laboratory plants were introduced into classrooms, there was an increase in the interest of the students in this subject and their positive response. The first section of the seminar provided descriptions of basic structures that could be used. Two of them are incorporated by the finalized method (system with DC motor and RC circuits) plus includes a temperature sensor. This could be used after further extension for a third temperature regulation function too. This paper implemented an example work with the mentioned laboratory plant in the next section of the article. This was a full cycle of controller design using one of the methods used for designing PID controller. Experimenting each component helps students consider the individual problems that that occur during the process. It's also possible to use this laboratory plant to try to solve certain problems from the control theory. This may be other methods of designing PID controllers, for example the Ziegler-Nichols experimental system. In case of switching between manual and automated mode it is also possible to demonstrate wind-up effect and methods of its suppression or bumpless operation. An important set of tasks is the implementation of discrete controllers using algebraic methods, where the sampling time and hence the replication of the control algorithm is considerably longer than with methods based on a continuous controller design. By the modern control theory space monitoring will be used, as the laboratory plant often allows to calculate the current movement through the motor and thus to assess the variables of the state.

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