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# IMPLEMENTATION OF A USER INTERFACE FOR AN EDUCATIONAL MATERIAL SYSTEM TO EASILY EXPERIENCE THE DIFFERENCES IN MOTOR CONTROL THEORY

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Abstract. *This paper describes user application interfaces for the educational teaching material system. Our previous research researched the "Educational Teaching Material System" to understand the difference between the control methods learned in university classes and the actual control methods after employment. This system aims to make it easier for students to observe the difference in motor responses when different control methods are used. Moreover, it makes students understand the correspondence between the theory and the phenomena using a motor control system. However, this system does not have a user application interface for use. Thus, users must directly change the program code to change the control method and each parameter. Therefore, in this research, we decided to develop application interfaces for the "Educational Teaching Material System", which aims to create an easy system for students.*
**Keywords:** Embedded system, DC motor, Electrical education, Motor control theory, Motor control experiment system

1. **Introduction.** In recent years, the importance of electrical energy such as a motors' power source has become more and more in resolving global environmental problems. Thus, electrical motors will be widely used not only in industrial fields but also as sources of motive force in electric cars. However, in the university lectures about electrical engineering, such as motors, there are not enough changes in response to changes in social conditions. Moreover, in university lectures, students learn motor control theory and technique with a textbook, so it is difficult for them to feel the difference between the control method they learn in class and the control method using the actual motors.

Therefore, educational teaching material systems for the motor in university electrical engineering education is widely needed, and there is much research in many fields. These researches target to develop a learning system of PID control system [1,2,4], and develop laboratory education system using the embedded computer [6,9]. Another approach, a

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commercial robot, and a commercial DC Motor Kit, are used as low-cost laboratory systems and motor control targets [6].

On the other hand, our central research theme is that students experience the actual movement of a motor. To realize this, we are researching and developing educational teaching material systems that allow students to experience motor control based on motor control by the embedded system. These systems aim to bridge knowledge learned by university lectures and motors used in embedded systems/electronics/mechatronics equipment. Our research using a DC motor took many approaches, such as the SH-2 base [7,8], Arduino base [5], and Web application base [3]. However, these systems keep the central theme of giving students motor control theory (P, PI, PID) via an actual motor. However, the primary purpose of these systems is to allow students to learn the theory of motor control (P, PI, PID) by using actual motors. On the other hand, our research aims to create a teaching system that allows students to experience how the knowledge and skills of the subjects they study at university are related to each other through motor control.

The system [5] in the previous study did not have an excellent interface to understand the control features as an educational material system, and it was difficult for students to understand motor control intuitively. Therefore, we thought that by visualizing motor control, it would be possible to realize a teaching material system that can help students understand motor control by quickly comparing control features and the differences between theoretical and actual operations. As a result, we realized an easy-to-use interface for users.

In this paper, we first discuss the details of the educational teaching material system based on the previous studies. Section 3 describes the user interfaces researched in this study. Evaluations of the educational teaching material system with the user interfaces are also presented in Section 3. Finally, Section 4 concludes this paper.

## 2. Educational Teaching Material System.

**2.1. System components.** The basic configuration of this educational teaching material system and the outline of the whole system are shown in Figure 1. This educational teaching material system consists of (1) computer section, (2) embedded processor section, (3) motor driver section, and (4) control target section (DC motor). Figure 2 shows the educational teaching material system which we are researching and developing using an embedded computer.

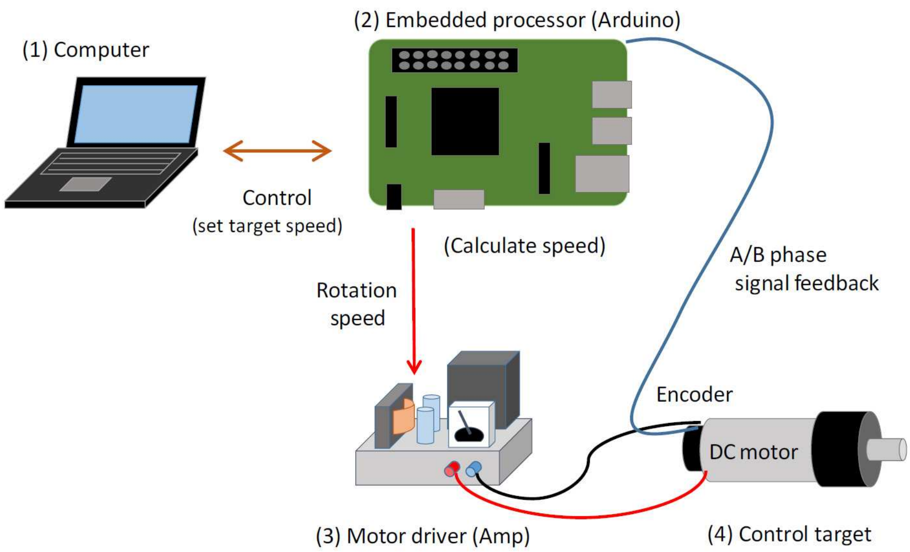


Figure 1. System diagram

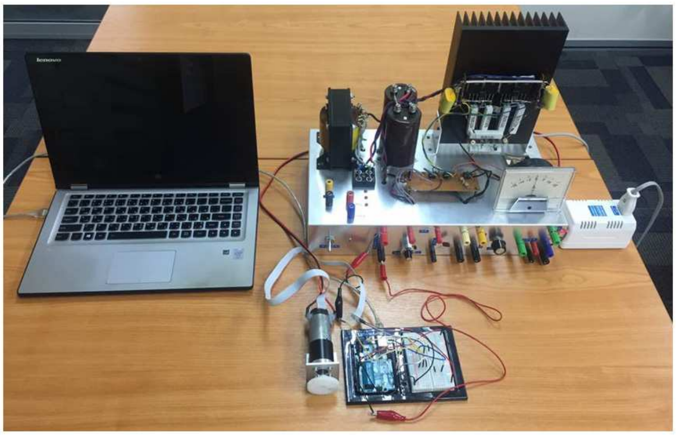

Figure 2. Educational teaching material system

In the PC section, we use the personal computer for various operations such as turning the system ON/OFF, setting the target speed, controlling the rotation direction, and data display. The PC does not control the motor directly; it controls via the embedded computer (Arduino Uno).

In the embedded processor section, the Arduino Uno is used as the embedded computer. The Arduino Uno is connected to the motor driver's controlling pins that control the rotation speed by PWM signal. A motor control system which is a PID controller, is implemented to the Arduino Uno by C Language, and the Arduino Uno controls the motor using motor driver by user operations input.

In the motor driver section, we use the motor driver as a power supply for the motor, and a DC linear amplifier is used in this system. Figure 3 shows the motor driver that we are using in this education teaching material system. The motor driver has a large heat sink to prevent thermal runaway caused by the bipolar transistor for current amplification, and the motor driver has a large heat sink.

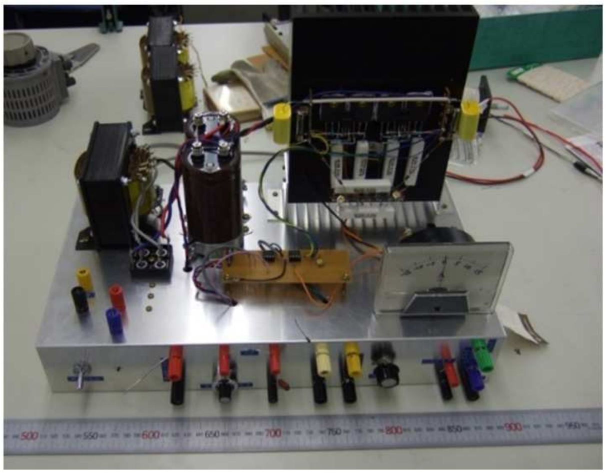

Figure 3. Motor driver

In the control target section, we had selected a DC motor (made by Maxon) incorporating an optical rotary encoder. It consists of a planetary gearhead, re-max graphite brushed motor, and a three channels encoder sensor with a line driver.

2.2. **Motor control system (software part).** Figure 4 shows a schematic diagram of the motor control system, with the control system implemented in the embedded computer shown as a dashed line; the control system implemented in the Arduino Uno checks the current speed and status of the motor and controls the speed of the motor.

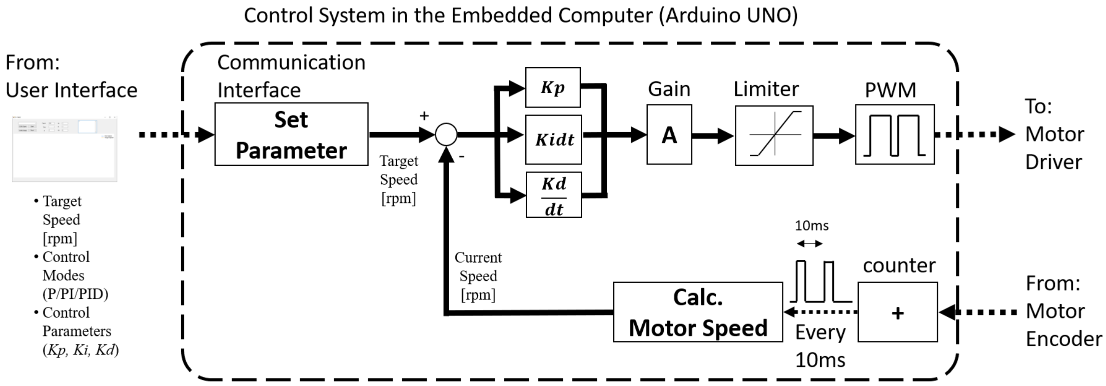


FIGURE 4. Motor control system diagram

In the system of the previous study, the target speed, amplification, and the parameters necessary for motor control were provided as variables in the source code of the system. Therefore, when changing the contents of the motor control, the program had to be rewritten directly and compiled/downloaded each time, as shown in the sample program example in Figure 5.

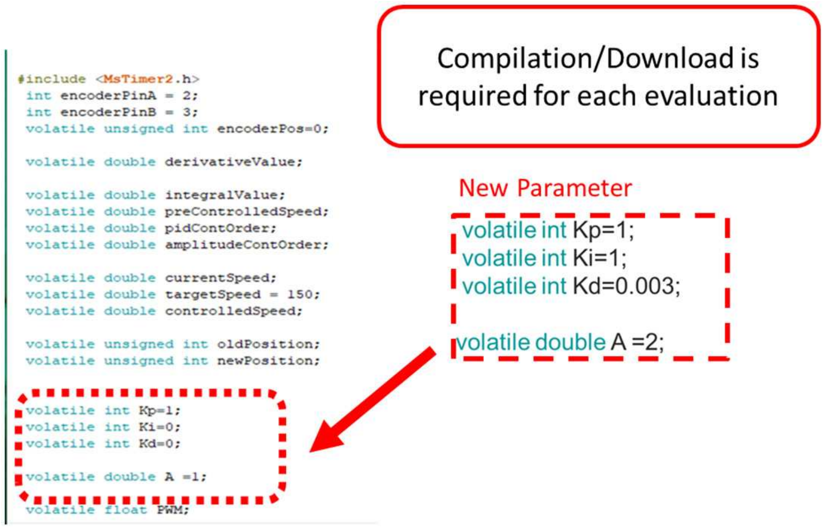


FIGURE 5. How to change parameter setting (sample program code)

In this research, a communication interface to the user interface has been added to the control system. The communication interface receives operation command information (motor speed [RPM], control mode (P/PI/PID)), and control parameters ($Kp, Ki, Kd$) related to motor control from the user interface created in this research and controls the motor. First, the control system receives the encoder pulses from the optical rotary encoder and calculates the motor speed every 10ms. After calculating the motor speed, it compares the target motor speed with the current motor speed to update the speed control command. Next, the PID controller calculates the new PWM parameters (new motor speed) using the control parameters $Kp$, $Ki$, and $Kd$. Finally, the new PWM parameters are set, resulting in a change in the speed of the motor. The control system outputs the motor operation information to the user interface through the communication interface. As a result, the user interface can draw a graph about the system's behavior.

## 3. User Interface.

**3.1. Graphical user application interface.** In this research system, we develop and add a user interface that was insufficient as an educational teaching material system based on the system of the previous research. In this research, "Visual Studio2017" was used to develop the user interface, and "Interface of motor control system for teaching materials" was developed as a Windows application. Figure 6 shows the connection diagram of the user application interface, PC, and Arduino Uno. "Interface of educational teaching material system" is used as a user interface for setting each parameter and displaying the control result. The control system with the communication interface added this time is implemented in the Arduino UNO, which controls the actual motor and gets the motor control results log.

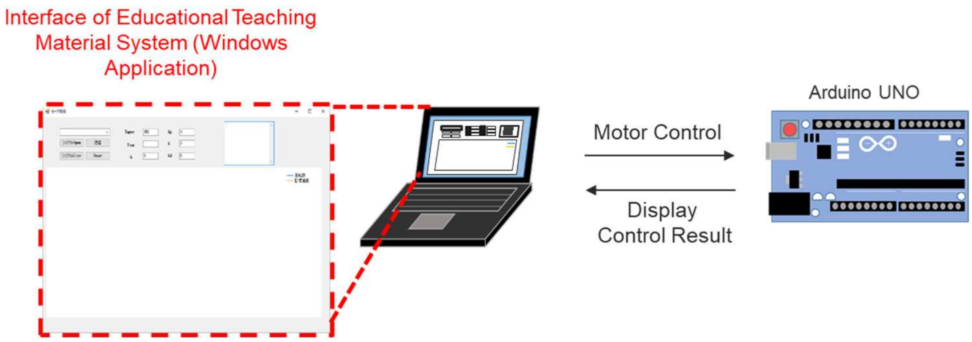


FIGURE 6. Connection diagram of the user application interface

Figure 7 shows the experimental results of PID control with a target speed of 150 [rpm], amplification A = 1, $Kp = 1$, $Ki = 1$ and $Kd = 0.003$ on the screen of the user application interface developed in this study. The control system implemented on

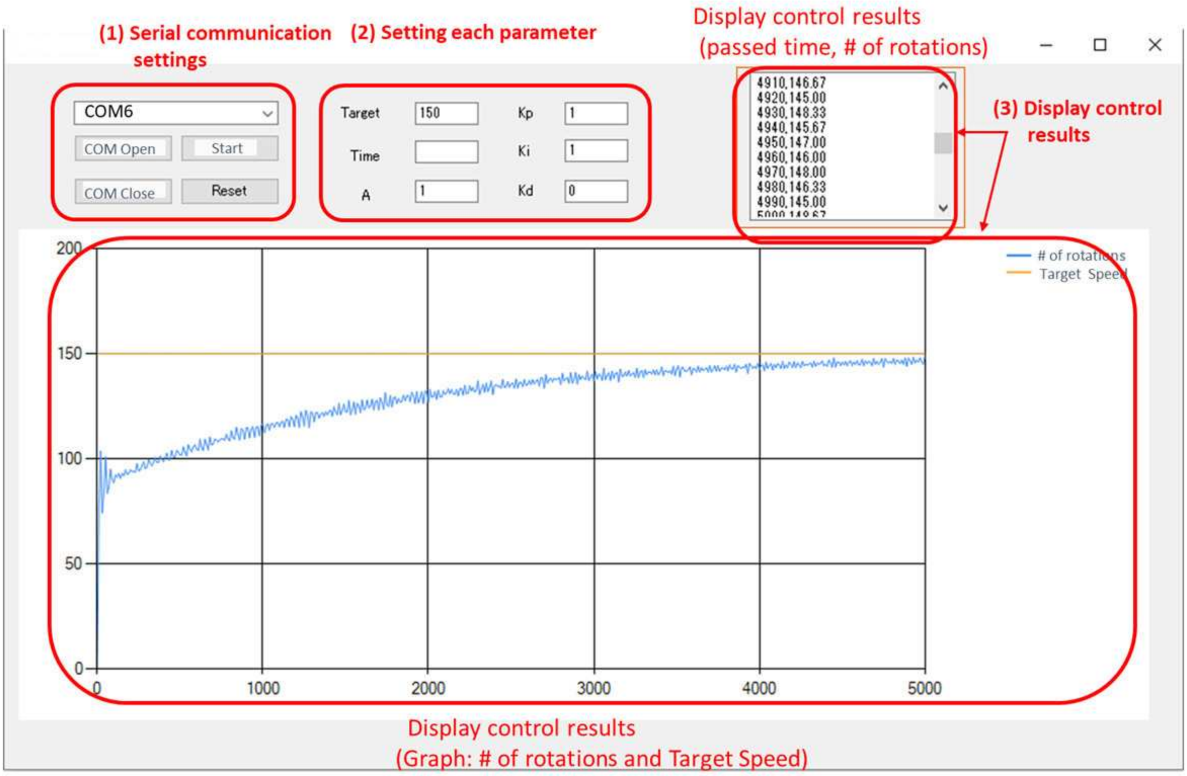


FIGURE 7. User application interface with experiment result

the Arduino UNO communicates with the user application interface running on the PC to receive commands related to motor control. The control system implemented on the Arduino UNO communicates with the user application interface running on the PC to receive orders related to motor control. Therefore, the interface has buttons and input fields for "(1) Serial communication settings (PC to Arduino UNO)" and "(2) Setting each parameter (Target, Time, A, $Kp$, $Ki$, $Kd$)" to enable communication and control settings. In addition, it has a result display field "(3) Display control results (time elapsed, # of rotations)" to display a graph of the control result.

To control the motor using the user application interface you have created, first enter the target speed, amplification, and control method in the "(2) Setting each parameter". Then, use "(1) Serial communication settings" to set the port number of the Arduino.

After that, set the COM port number to which the Arduino UNO is connected using "(1) Serial communication settings" and press the "Start" button to send the parameters for motor control from the user application interface to the control system on the Arduino UNO. The control system on the Arduino UNO will then control the motor.

As the result screen in Figure 7 shows, the user application interface can display the motor control results (elapsed time and rotation speed) according to the set parameters (PID) in numerical values and graphs. The vertical axis is set to rotation speed [rpm] and the horizontal axis to elapsed time [msec] in the graph axis setting. Thus, with this user application interface, students can efficiently conduct motor control experiments with different P, PI, and PID parameters. Moreover, there is no need to rewrite/compile and download the program code. Using this system allows students to easily observe the effect of changing the gain parameter "A" of the P-control. Therefore, students can experience with an actual motor that an insufficient amplification factor of the P-control results in a large steady-state error relative to the motor's rotational speed, while an excessive amplification factor results in poor system stability.

3.2. **User interface to experience the difference in P-control/I-control.** In this study, in addition to the graphical user interface function, we also implemented a system (experienced-based interface) that allows students to experiment to see if they can stop the rotation of a motor by hand to deepen their understanding of motor control.

Figure 8 shows the system, and it shows how the students try to stop the motor rotation by holding their arms when the motor rotates at low speed in P-control and I-control, respectively. By using this material, students can experience the difference between P-control and I-control; when P-control controls, students can experience that they can stop the motor. However, when I-control controls, students can experience that even if they try to stop the rotation and stop it once, the rotational force will increase because of the

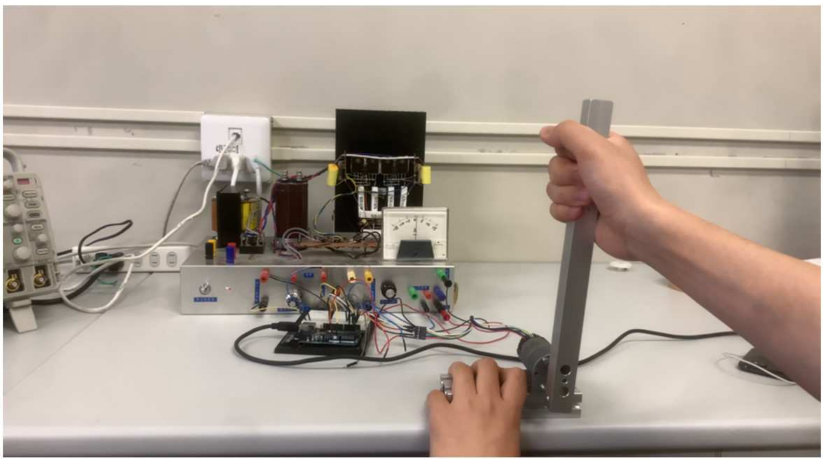

Figure 8. User interface to experience the difference in P-control/I-control

integral control, and the motor will inevitably run. Thus, using this teaching material, students can experience the difference in motor operation between proportional control (P-control) and integral control (I-control) by using an actual motor.

3.3. **Preliminary evaluation of the system.** As a preliminary evaluation, ten fourth-year university students belonging to a laboratory in the Department of Electrical Engineering used this system and conducted an evaluation. They had studied DC motors in lectures and experiments. However, the class content on motors was theoretical, and they did not have a good understanding of the actual operation. Therefore, before using this system, they did not understand the essence of the difference between P-control and I-control, even though they had done student experiments on motor control in their third year of undergraduate studies.

However, by using this system, they seemed to have understood the essence of the difference between P-control and I-control because they had the following impressions.

Therefore, they got the following impressions using this system.

- I think I understood the difference between P-control and I-control.
- I did not think that P-control would not reach the target speed.
- I feel like I understand motor control now.

4. **Conclusions.** In this paper, interfaces of the educational teaching material system were described. These interfaces were implemented to aim to easily experience the difference in motors response by different control methods. The graphical user interface makes it easier to configure the settings of the education teaching material system. The user interface to experience the difference between P-control and I-control will aid in learning the motor control system.

From interviews of students, students seem to understand the difference of motor response controlled by P-control and I-control. We could not make a good evaluation in this research because we could not get many students to use it. In the future, we would like to evaluate the effect of using the system by using it in student experiments.

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