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Research Article

Comparison of the Questionnaires Before and After the Experiment

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ABSTRACT

The aim of the present study is to improve the understanding of the control engineering for university students through the experience of the control experiment, and hence an experimental device is developed. The students are educated the control engineering using the device, and the educational effect is evaluated. In the present study, the students take examinations for the control engineering before and after the experiment, and the effect is evaluated objectively.

1. INTRODUCTION

In the engineering education, the control engineering is educated for the students who have taken mathematics, applied physics, mechanical engineering, electrical engineering and so on. The control engineering is not easy for students to understand intuitively only by the classroom lecture. Therefore, effective educational methods are demanded [1,2]. To realize the class of the control engineering through an experience of the control experiment, experimental devices have been developed [3–5]. In Sato et al. [3], an experimental device that combines a model helicopter with a computer screen is developed, and students experience flight control. In Yasui et al. [4], a flotation device is also developed, and the buoyancy generated by a propeller is adjusted to control the altitude of a floating object. However, in the conventional studies [3–5], because the educational effect is evaluated subjectively, it is not evaluated that students understand correctly. On the other hand, in the present study, questionnaire is answered before and after the experiment, and the difference between the questionnaires. As a result, the educational effect is evaluated objectively.

2. EDUCATIONAL OBJECTIVE

The educational objective for developing an experimental device is that engineering students understand the following control actions:

- Manual control
- Automatic control
- Feedback control
- Feedforward control
- Proportional control

3. EXPERIMENTAL DEVICE

The developed experimental device is shown in Figure 1. In the device, and its schematic diagram is illustrated as Figure 2. In the device, the arm is rotated by a motor, and the control objective is to make the rotation angle of the arm be settled at the specified angle. In the manual control, the torque generated by the motor is changed by tuning a volume manually. In the automatic control, the rotation angle of the arm is measured, and the torque is decided by a computer using the measured angle.

Using the device, the students experience the control actions and can understand these meanings intuitively. The control actions implemented in the device are listed as follows:

- Manual control
  - Feedback control
  - Feedforward control
- Automatic feedback control
  - Small proportional gain
  - Middle proportional gain
  - Large proportional gain

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In the manual feedback control, the students recognize the rotation angle of the arm by watching with students' own eyes. Conversely, in the manual feedforward control, the students tune the volume manually without watching the arm to make the rotation angle be specified angle. Because it is difficult to control the rotation angle manually regardless of whether watching or not, the students can understand the usefulness of the automatic control. The feedforward manual control is naturally more difficult than the feedback manual control.

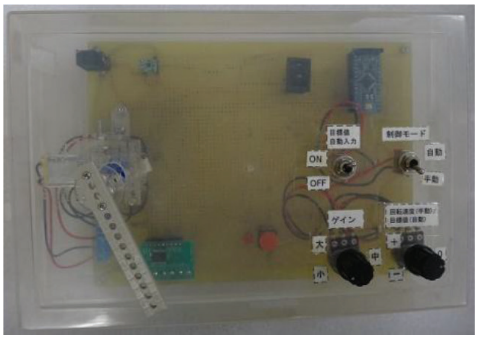

Figure 1 | Arm control device.

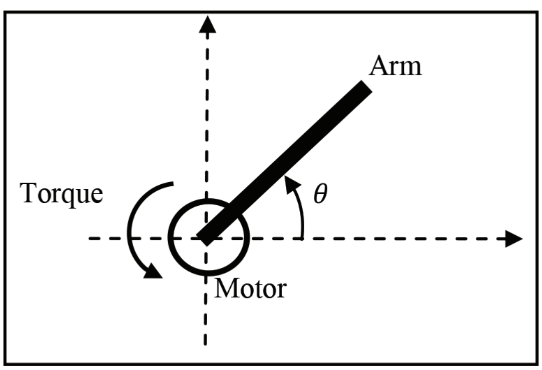

Figure 2 | Schematic diagram of the experimental device.

In the automatic control, the control input $u(t)$ is decided by the following control law:

$$u(t) = k_p(r(t) - y(t))$$

where $r(t)$ and $y(t)$ are the specified reference angle and the rotation angle, respectively. k_p is the proportional gain and is set to 1.0 (small), 2.2 (middle) and 5.0 (large). In the automatic control, the rotation angle measured in the controller is saved as the electric data, and the students can confirm the measured data after control experiment.

4. EVALUATION

To objectively evaluate whether the educational objective is achieved, the students answer the questionnaire shown in Table 1 before and after the experiment. The questionnaire consists of 19 questions, the correct answer rates are depicted in Figure 3. In the figure, the blue bar shows the correct answer rate before the experiment, and the red bar shows after the experiment. Further, the green bar shows the difference between the before and after experiments.

Figure 3 shows that most of the students understand the mechanisms of the manual control and the automatic control and understand little about that the stability and the tracking performance can be worsened by the feedback control. Since the rates of Questions 9 and 14 of after experiment are increased compared with those before experiment, the number of the students who understand that the tracking performance can be improved and worsened by the feedback control and the feedforward control, respectively, is increased by experiencing the control experiment. On the other hand, from Questions 7, 12, and 13, the number of the students who misunderstand that the stability and tracking performance can be changed by the feedback control and the feedforward control, is increased.

Table 1 | Questionnaire before and after experiment

Term in control system	Questions	Number in Figure 3
Manual control	Manipulated amount is decided by human	1
	Manipulated amount is decided by other than human	2
Automatic control	Manipulated amount is decided by human	3
	Manipulated amount is decided by other than human	4
Manual control vs. automatic control	Manual control structure is simpler than automatic control	5
	Automatic control structure is simpler than manual control	6
Feedback control	Stability can be improved	7
	Stability can be worsened	8
	Reference tracking performance can be improved	9
	Reference tracking performance can be worsened	10
Feedforward control	Stability can be improved	11
	Stability can be worsened	12
	Reference tracking performance can be improved	13
	Reference tracking performance can be worsened	14
Feedback control vs. feedforward control	Feedforward control structure is simpler than feedback control	15
	Feedback control structure is simpler than feedforward control	16
Proportional control	Response speed can be improved	17
	Response speed can be worsened	18
	No steady-state error	19

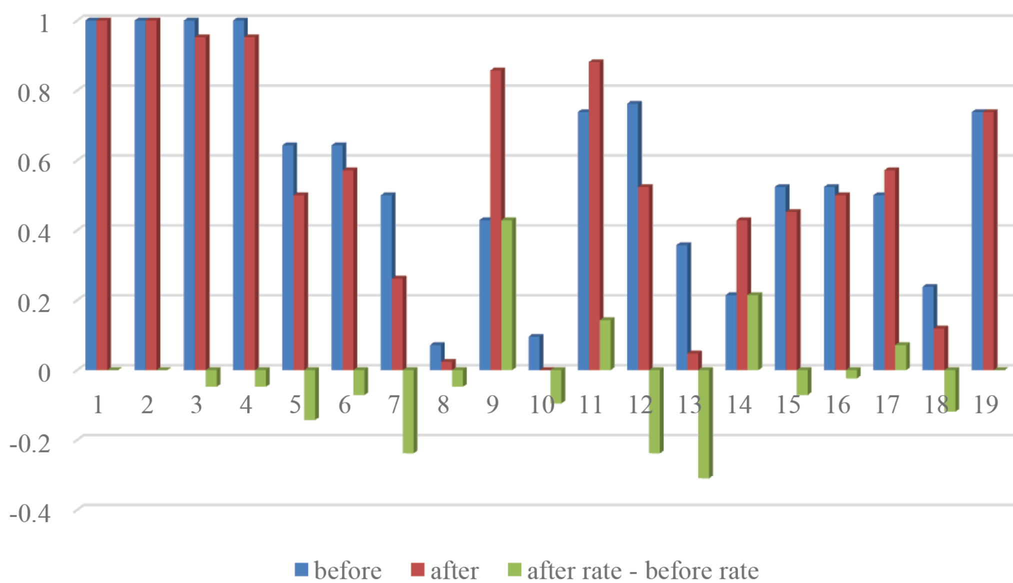

Figure 3 | Correct answer rate before and after experiment.

5. CONCLUSION

In the present study, the educational effect using the experiment is evaluated objectively. In the developed device, since the integral and derivative compensations are not implemented, and the compensations should be introduced. As the evaluation result, not all understanding rates are increased with the current teaching method. Therefore, our future work is to enhance the control engineering lesson to increase the correct answer rate after experiment.

CONFLICTS OF INTEREST

The authors declare they have no conflicts of interest.

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