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Design and Development of a Myo-electric Controlled Artificial Hand

- Practical Course of Junior High School Students-

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Abstract: Faculty of Science and Technology, Keio University provides an opportunity for junior-high-school students to give a chance to attend a course of "Design and Development of a Myo-Electric Controlled Artificial Hand" as well as other scientific and technological courses. Junior-high-school students who enrolled the course study neurophysiology, electric circuits, computer programming that are the equivalent level of sophomore or junior classes in university. With adequate assistance of senior university students, junior-high-school students overcame the difficulties of the topic enthusiastically. We concluded that it has benefits for junior high school, and their students who have intellectual curiosity and interest in this field.

Key words: Artificial hand, Myo-electric control, Junior-high-school students, Hot Soup Processor

1. Introduction

Faculty of Science and Technology, Keio University provides an opportunity for junior high school students to attend university level lectures conducted at junior high school by experts, and received instruction from them. Students voluntarily attended the orientation of lectures and choose a course. Fifteen to 20 second- and third-year students register this course every year. This report describes the specifics of the lecture course entitled “Manufacturing a Myo-electric controlled artificial hand”, and analysis of its educational effectiveness.

The course was carried out for six days. The first day, motion physiology and its disorder were lectured. The second day, the way of moving a robot hand by a personal computer was introduced (mainly programming). The third day, construction of H bridge including soldering practice was carried out. The fourth day, students constructed a bio-signal amplifier, and tried to move the robot hand controlled by electromyogram (EMG). The fifth day, students tried to move the robot hand controlled by EMG. The last day, students tried to move the robot hand controlled by EMG, and received a lecture of introduction of cutting edge research of bio-instrumentation. Each day the students attended the course for three hours.

2. Materials and Methods

2.1 Lecture Content

A myo-electric controlled artificial hand can be moved by triggering the motor with electromyogram when it exceeds a preset threshold, enabling actions such as grasping and releasing objects to be performed [1]. The lectures first covered basic material regarding people with mobility impairments and the physiology of motion. The subsequent study curriculum consists of studying robot hands, studying programs for moving robot hands, and practical work in which a bio-amplifier to drive this course is built step-by-step.

2.2 Manufacturing a Myo-Electric Controlled Artificial Hand

An outline of the actual system that was manufactured in the lectures is shown in Figure 1. This system was designed so that it could be constructed almost completely out of devices built using readily obtainable materials, to be as simple as possible, and to incorporate only the essential elements of a myo-electric controlled artificial hand—measurement of muscle activity, its recognition by a computer, and the driving of an external device (an electrical hand).

The following points were taken into consideration in the design of practical work involving the production and control of a myo-electric controlled artificial hand constructed using readily available materials and devices.

A myo-electric controlled artificial hand consists of a pre-amplifier that has high input impedance and amplifies electromyographic (EMG) signal, a main amplifier that amplifies the EMG signal that can be read by a personal computer (-5 to +5 V), and a program that detects the EMG and opens or closes the artificial hand accordingly. The following items are commercially available with reasonable price (Figure 1 and Table 1).

2.3 Bio-amplifier

The mechanism of a bio-amplifier is junior level material and requires a wide range of basic knowledge. Hence, a university teaching staff outlined the electrical functions of components, such as resistors, capacitors, diodes and operational amplifiers. Then the students built the circuits by assembling and soldering them in accordance with a circuit diagram that was handed (see Figure 2).

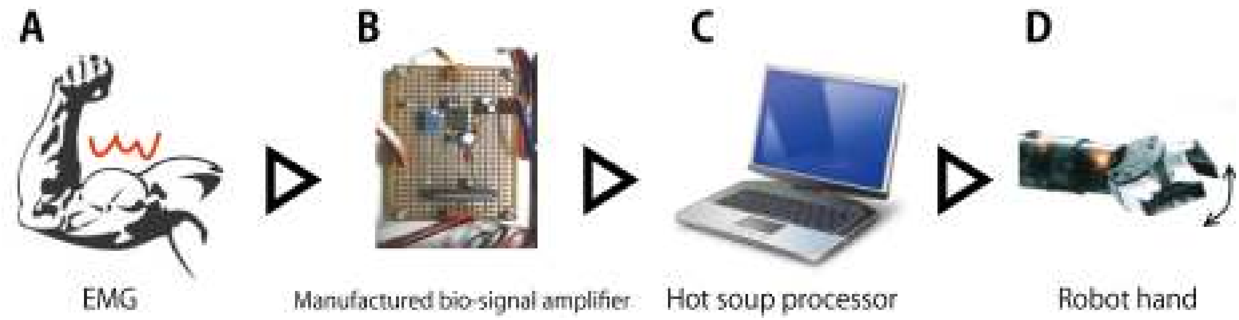
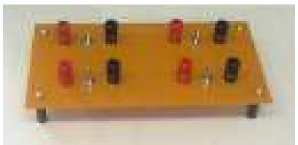


Figure 1 Outline of the myo-electric controlled artificial hand built during the class work. (A) The changes in electrical potential that occur when the muscle contracts are transmitted to an amplifier by means of electrodes on the surface of the muscle. (B) The electrical potential is amplified approximately 1000 times by the bio-signal amplifier constructed during the class work. (C) The amplified signal is recorded by a program written by Hot Soup Processor (HSP). (D) Opening and closing of a robot hand is controlled by HSP program.

Table 1 Equipment for the construction and control of a myo-electric controlled artificial hand.

Equipment	Details
Robot hand 	Robot arm(MR-999, EK Japan) (5000 yen) The wirings and constructions are visible inside a translucent case, enabling the structure of the circuits and the movement mechanisms of the motor and gear wheels to be observed.
H bridge control circuit 	H bridge control circuit built by the students (800 yen) By manually changing the mechanical switches, students can learn the principle of changing the rotation direction of an electric motor.
Personal computer	General-purpose laptop (130,000 yen)
programming environment	Hot Soup Processor (freeware) A number of reference books aimed at junior-high-school students available, allowing students to study the subject for themselves after the classes.
Bio-sensor	Bio-amplifier built by the students (cost of materials: 3000 yen)

2.4. Programming language

Hot Soup Processor was used for the programming language, since

(1) The programming environment can be set up easily and is constructed in such a way that students who wish to do further research can pursue study on their own.

(2) There are reference books [2][3] on the language aimed at junior-high-school students, enabling students who would like to carry out further research to do so.

(3) The language is an interpreted language (like BASIC), in which each successive source code instruction is interpreted and executed—not a compiled language (such as C) in which the program is first converted into executable form.

(4) The language can control external devices (a bio-amplifier and a robot hand), via a USB port.

(5) Freeware language, because of economical reasons.

The programming involved sophomore level

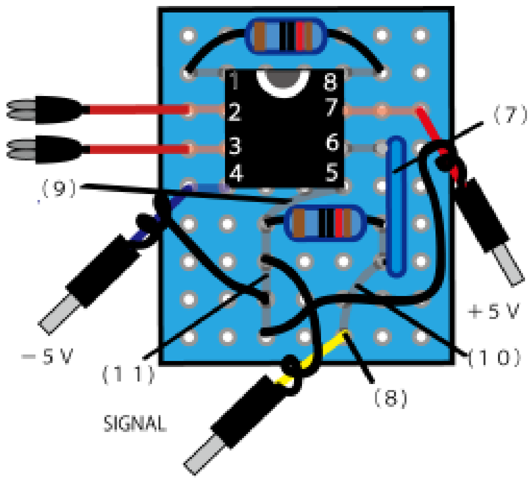


Figure 2 Design diagram of the bio-amplifier (extracted from a hand-out)

content, such as screen display of characters, variables, conditional branching based on the if-else statement, and graphical user interfaces. These concepts were handled by presenting the program operation steps in animation form in the lectures, and were further amplified in a workshop format in which the students tried out each command one by one for themselves, to see how they functioned.

2.5 H-bridge control circuit

An H-bridge control circuit is used in an electric hand to switch the direction of the voltage applied to the motor. In order to understand the structure of this control circuit, four mechanical switches were used. The switches could be set manually, and this made the students think about which combination of switch ON/OFF settings would change the direction of the current.

2.6 Robot hand

A robot arm (MR-999, EK Japan) was used, since internal structures (such as a motor and gears) could be observed, and junior-high-school students could assemble it for themselves, and the price was reasonable (5,000 yen).

2.7 Short Essays

Almost every week, students were required to write an essay on a 900-character form reviewing the content of each class and point out interesting topic or questions. By these essays, the teaching staff could stimulate the students to reach more profound understanding of the content of the lectures and to reflect on the work curriculum. The short essays were returned to the students next week. In the course of this process, the students were able to practice putting their thoughts in order and expressing themselves in writing. Analysis of these essays enabled the instructors to judge whether or not the lecture content was appropriate and to know the points the students hard to understand.

2.8 Publishing Class Work

Videos of this class work have been uploaded to the Internet as OpenCourseWare (OCW), so as to spread awareness of these efforts to the public domain. They can be found at <http://ocw.dmc.keio.ac.jp/j/Sc_and_Tech/06R-001_j/index.html>.

3. Results

The lecture course consisted principally of the following five topics:

(1) Basics of human motor control mechanism
(2) Constructing a bio-amplifier
(3) Programming
(4) Constructing a robot hand
(5) Myo-electric control of a robot hand.

By analyzing the students' essays, the follows items were found:

3.1 Basics of Human Motor Control Mechanism

Students listened to the lecture of the mechanism of the brain and the nervous system which controls motion, and its disease, and they learnt about the mechanism of the EMG that would be used for the myo-electric controlled artificial hand. In the lecture, the structure of nerve cells was compared to that of body cells. Care was taken to make it easier to understand how the action potential is conducted and transmitted, by using computer graphic images.

A demonstration was also carried out to make the muscle contraction using commercially available low-frequency therapy equipment, in order to give the students a real sense of how electricity flows through the nerves. The student who was the subject of the demonstration seemed to find it quite hard to get to grips with this sensation that he had never experienced before, saying “I was surprised-My hand moved even I don't moved it.”

3.2 Constructing Bio-Amplifier

A bio-amplifier was constructed which amplifies the electrical muscle (myo-electric) activity received by electrodes and an operational amplifier.

The assembly of the bio-amplifier was explained on hand-outs, which described how the components should be arranged and the order in which they should be mounted on a universal circuit board. These were distributed to the students for reference, enabling them to construct the bio-amplifier.

The instructors taught the students how to solder and to avoid burning, even students who were new to soldering made good progress, as can be seen from their essays such as, “Before I knew it, mounting a capacitor just became second nature, and my hand didn’t tremor anymore.” There were also a few students who came to realize that soldering is an important technique in the production of modern electronic devices, as shown by the student whose reaction was “I wasn’t really aware of this before, but it seems that soldering is quite important technique.”

3.3 Programming

In the practical training on programming, programs were coded in freeware of HSP to open and close the robot hand in accordance with the level of muscle activity. Initially, a few of the students had difficulty inputting so many English letters, while a few students could not understand how a computer processes information in a certain order. However, by reviewing examples of program source codes, they were gradually able to get used to it. Reactions from the students included the following: “I think it’s fun to study programming, because if I understand the grammar, I can write programs just as I like.” and “It’s really hard to use the commands which I don't know. I must find them from the manual. I admired the university students, who could use them from memory.” It seems that once an initial hurdle of properly understanding the grammar of the programming language was overcome, they started to feel that they could learn programming for themselves with trial and error.

3.4 Constructing Robot Hand

One week before the start of the class work, the components for the robot hand and an assembly manual were distributed to the students. As the robot hand was to be used in the first lecture, the students were instructed to fully assemble it beforehand. Student reactions such as "I finished assembling the robot hand straight away". "It was probably assigned as homework since I can do it by myself". "It’s exciting, as I never imagined class work like this." showed that even before the class started, the students seemed exciting.

3.5 Myo-Electric Control of Hand

After completed the bio-amplifier, they connected to electrodes attached to the surface of their arm muscles, and the output of the bio-amplifier was converted by HSP program into the signal for opening and closing the robot hand. The students verified whether the robot hand would move when they actually turn on the power switch. The finished article was a genuine myo-electric controlled artificial hand system.

Several students did not successfully complete this stage, with their myo-electric controlled artificial hand system either experiencing malfunction or failing to function at all. However, a few students learned from these failures and gained insight into manufacturing, as shown by the following essays: “‘Hardware’ is not at all unchanging, as the name implies. A device that works one day will not always work another day. I learnt that, because of this, it is important to make devices safer and reduce the risk of malfunction. Trouble spots must not be left unfixed.”

4. Discussion

In the course of constructing a myo-electric controlled artificial hand, the students learnt about topics that they would never have encountered in the junior-high-school curriculum, such as constructing robot hands, wiring bio-instrumentation amplifiers and other electronic components.

The two factors that enabled junior-high-school students to study university-level content would seem to have been (1) that a group of students with a high degree of interest in scientific subjects was assembled, and (2) that the university-level research was simplified and practical training was conducted with ample support. This case study demonstrated that junior-high-school students are capable of receiving university-level curriculum. It means that nurturing students’ interest and intellectual curiosity in mathematics, science, and technology, make them aware of potential future career options, and produce a substantial level of human resources for science and technology.

From our experience we can say that with the help of university instructors junior high schools can teach higher level science and technology curriculum. It has benefits for junior high school, and their students who have intellectual curiosity and interest in this field.

Acknowledgment

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