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Robotics Education: Development of Cheap and Creative EMG Prosthetic Applications

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Abstract— **We propose a novel robotic developmental kit for educational purpose. It helps junior high / high school / university students to understand recent prosthetic technology and, moreover, to provide a chance to produce creative prosthetic applications for short time at low cost. The developmental kit consists of an EMG-to-Motor controller and a wire-driven device. For delivering the cheapness and easiness to students, we demonstrate three prosthetic applications based on the kit: (1) Simple Prosthetic Hand is a mimic of commercial prosthetic hand. It illustrates that low-precise design achieves cheap production cost and sufficient function as a prosthetic hand. (2) Rock-Scissors-Paper Prosthetic Hand is based on prosthetic hands for research use. It clearly illustrates EMG-to-Motion discrimination processes by displaying real signals. (3) EMG Presbyopia Spectacles shows the possibility that beginners design creative prosthetic applications based on daily activities. Finally, we report two educational courses we have conducted for junior high and high school students.**

I. Introduction

Most of available educational robotic courses tend to offer controller-focus contents because of the difficulties that beginners design their original structure for limited course hours. Those courses normally provide robot kits like plastic models (i.e., fixed design as humanoid robots and vehicle robots) and, after participants assemble pre-designed components, those robots are operated by the participants. That is, the participants do not experience to design robot structures and control robot motions. Meanwhile, LEGO mind storm provides participants to design both controller and structure of robots so that it greatly contributes to teaching how the robots work. However, those robots are mainly limited to vehicle robots so that they do not deliver recent technology, which participants are interested in. Thus, it is necessary to provide both creativity and knowledge of advanced technology in robot development in order to encourage participants' interest to science and technology. Especially, our target is junior high and high school students so that cheap cost is important component to design a robotic developmental kit.

Therefore in this paper, we propose a creative and cheap developmental kit for prosthetic applications, and introduce educational contents, which help to form participants' firsthand knowledge by demonstrating mimics of present technology.

This paper consists of the following: (1) we propose a cheap and creative robotic developmental kit for prosthetic applications; (2) we explain the details and significances of 3 demonstration applications; (3) we report educational courses for junior high and high school students.

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II. Proposed Developmental Kit

Generally, robot development is regarded as an expensive and difficult activity. However, it seems that expensive cost and technological difficulties are required only when developers focus on high-precise design. So, we focus on low-precise design and realize cheap, safe, and quick robot development.

Our proposed developmental kit consists of an EMG sensor, an EMG-to-Motor controller, and a wire-driven mechanism.

Table 1 Time to build and Material price list of demonstration kits
(* "Time to build" is determined by measuring the time the expert built.)

Demonstration kit	Time to Build	Material Price
EMG Sensor	60 min	$20
EMG-to-Motor Controller	90 min	$30

A. EMG Sensor

Among prosthetic applications, the sensor that measures bio-signal plays important role for its control. In our developmental kit, we focus on Electro-myo graphic (EMG) signals, which is the extracellular field potentials produced by muscles as shown in Fig.1.

Fig.2a shows a hand-made EMG sensor: the hand-made design emphasizes that even beginners are able to make the EMG sensor at cheap cost. The EMG sensor consists of a differential amplifier, notch filter, second order low pass filter, second order high pass filter, and non-inverting amplifier. The sensor is attached on skin along thick muscles as shown in Fig.2b and acquires original EMG signal, which is +/- 100 micro voltages, and the signal is amplified to +/-9V (100000 times) as shown in Fig.2c. Table 2 lists the specification of an EMG sensor.

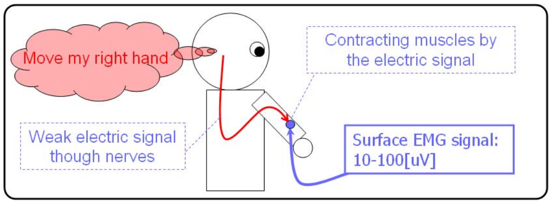
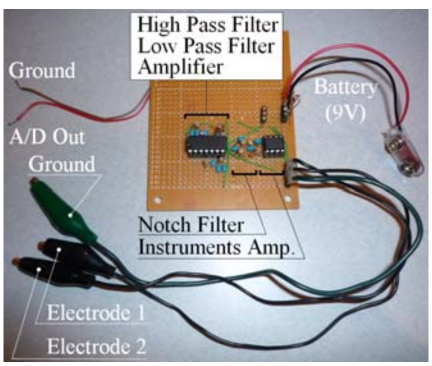


Fig.1 Conceptual diagram of EMG signals.

Table 2 EMG Sensor Specification

	Name	Function
1	Instrument Amplifier	1000
2	Notch Filter	Cutting around 50/60[Hz]
3	2nd Order High Pass Filter	Cutting lower freq. than 10 [Hz]
4	2nd Order Low Pass Filter	Cutting higher freq. than 500 [Hz]
5	Amplifier	100



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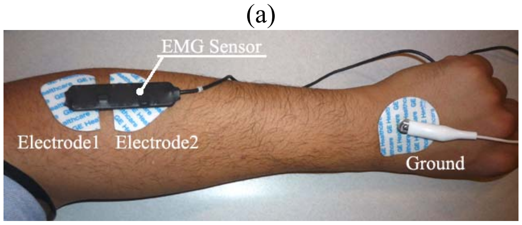

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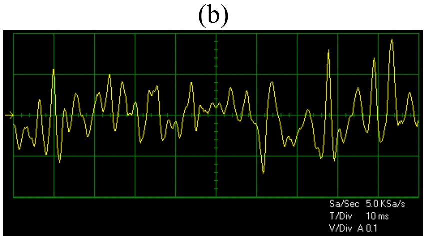


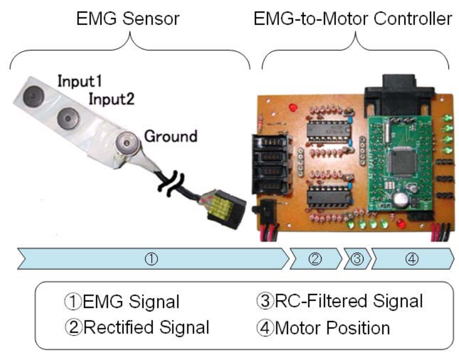
(c)

Fig.2 Plastic-bottle-based robots for demonstration. (a) Robot arm. (b) Step climber. (c) Passive dynamic quadruped (trot gait with one motor). (d) Simple locomotor that control by EMG. These videos are shown on my website http://www.koj-m.sakura.ne.jp/edutainment/index-en.html.

B. EMG-to-Motor Controller

Generally, it is difficult to apply EMG signals for motor control. So, for easy-use, we made an EMG-to-Motor controller, which apply only EMG amplitude information for control input. With this controller, beginners are able to operate robots as if motors are their muscles. Therefore, the controller helps to provide a hands-on learning of the prospective cybernetic technology (e.g., prosthetic hands and power assist machines).

The EMG-to-Motor controller consists of full-wave rectifier, RC low pass filter, and the microchip H8/3664 circuit (Fig.3b). The controller performs the following signal process: Then, the EMG signal post-process circuit functions full-wave rectifying and smoothing (cut-off frequency is 8.8Hz) in order to extract only amplitude of the EMG signal, which is equivalent to stress information of muscle (Fig.3). Finally, the signal is fed into an A/D converter pin of the microchip H8/3664, and a RC servomotor moves to desired angle corresponding to the amplitude information. In short, the stress information of muscle directly leads to the angle of RC servomotor.



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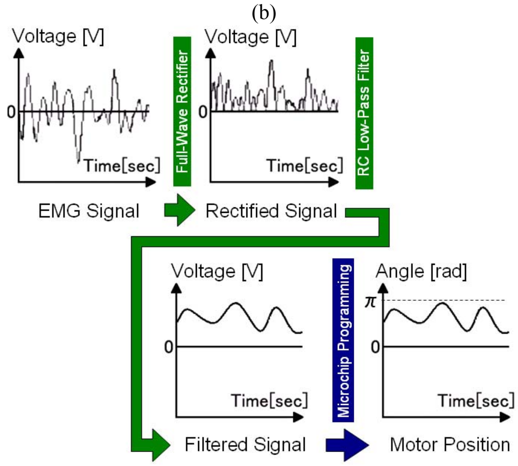

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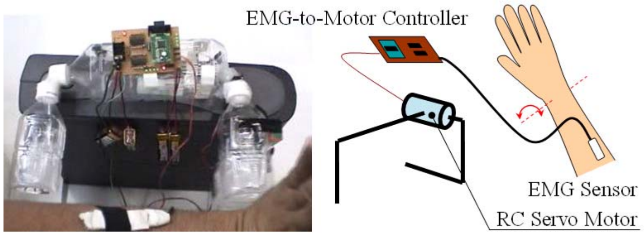
Fig.3 The EMG-to-Motor controller. (a) Hand-made EMG sensor. (b) Appearance. Left: an EMG sensor, Right: a circuit. (c) Signal processing in the controller.



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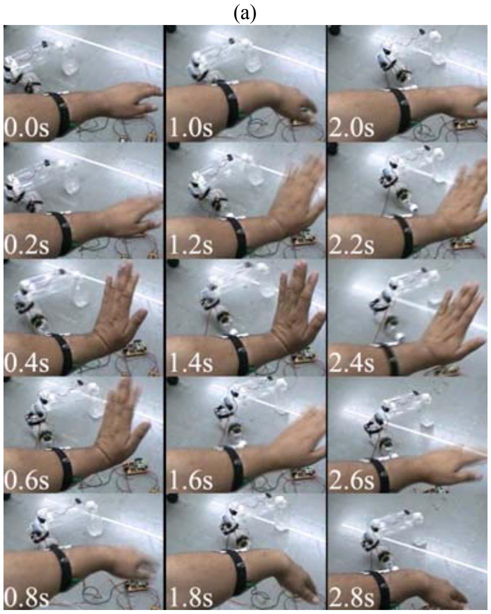


(b)

Fig.4 Robot control with the EMG-to-Motor controller. (a) Robot control system. (b) Working scene.

C. A Wire-Driven Device

A wire-driven device is shown in Fig.7. The mechanism serves place-free actuation so that it is easy to automate toys and tools with it. Thus, it is useful for beginners to realize their own conceptual design quickly, and they can improve their design and hands-on experiences in their trial and error.

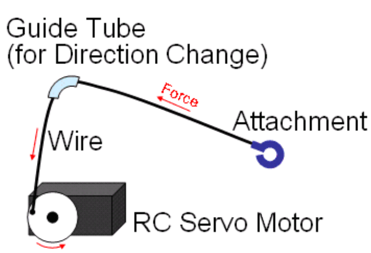


Fig.5 Conceptual diagram of a wire-driven device.

III. Prosthetic Applications for Demonstrations

We provide demonstration applications, which are low-precise-and-minimum-design mimics of present technology. We believe that the hand-built prosthetic applications greatly contribute to encourage participants' interest and gain understanding knowledge on both engineering aspect and biology aspect (Table3). Moreover, the combination of the controller and the proposed wire-driven devices give beginners opportunities to design new prosthetic tools, easily and cheaply (Table 4).

Table 3 Significance of demonstration prosthetics.

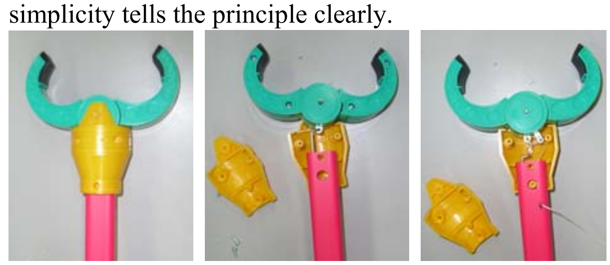
	Task
Simple Prosthetic Hand	To demonstrate the difference between commercial products and proto-types.
Rock-Scissors-Paper Prosthetic Hand	To encourage to understand how prosthetic hands for research work.
EMG Presbyopia Spectacles	To discuss on usability of the spectacles - location for the EMG sensor - motor control planning

Table 4 Time to build and Material price list of demonstration kits
(* "Time to build" is determined by measuring the time the expert built.)

Demonstration kit	Time to Build	Material Price
Simple Prosthetic Hand	30 min	$80
Rock-Scissors-Paper Prosthetic Hand	90 min	$150
EMG Glasses	60 min	$80

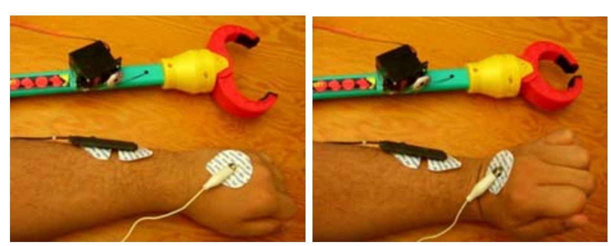
A. Simple Prosthetic Hand

As the first demonstration of prosthetic application, we built the simple prosthetic hand (Fig.6 and 7). It has one actuated degree of freedom, which is actuated with a wire-driven device and an EMG-to-Motor controller. The angle of the motor is determined by the stress of the muscles that an EMG sensor is attached. The mechanism is similar to the most popular prosthetic hand in the world [4], and we assume that its simplicity tells the principle clearly.



(a) (b) (c)

Fig. 6 Construction process of Simple Prosthetic Hand



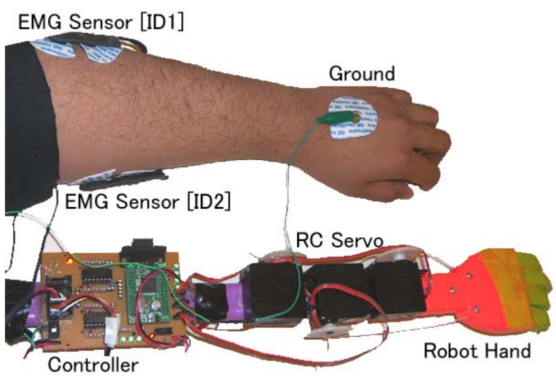
(a) (b)

Fig.7 Simple Prosthetic Hand with the EMG-to-Motor Controller. (a) The hand keeps open. (b) The higher amplitude the EMG becomes, the more tightly the hand closes.

B. Rock-Scissors-Paper Prosthetic Hand

As the second demonstration of prosthetic applications, we built "Rock-Scissors-Paper prosthetic hand" (Fig.8-10). It is the simplified version of the prosthetic hand for research use [5], and realizes three hand motions by discriminating human intention with two EMG sensors (Fig.10: EMG-to-Motion discrimination).

Fig.9 shows two developmental processes: (a) shows the toy-based development; (b) shows the printed sticker based development. The development process (b) is for developers, who cannot purchase the robot hand toy: (1) Fig.9b is printed out to a sticker sheet; (2) blue part is cut out by scissors; (3) finger links are taped as shown in Fig9b(left). Both structures (a) and (b) are the same (Fig.8b).



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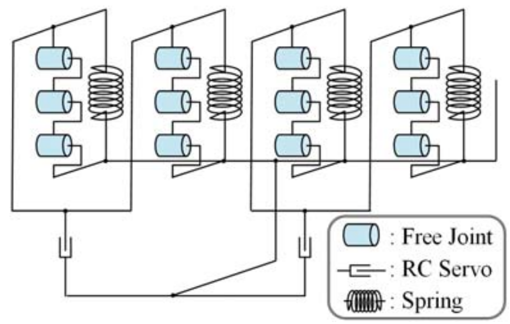


(b)

Fig.8 Rock-Scissors-Paper Prosthetic Hand. (a) Appearance. (b) The DOF diagram of the hand part.

(a)

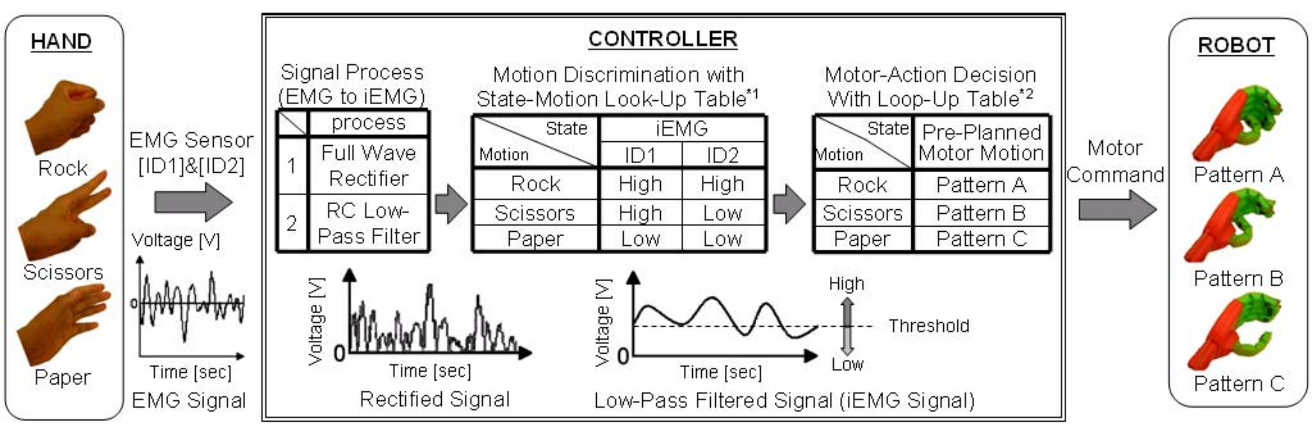
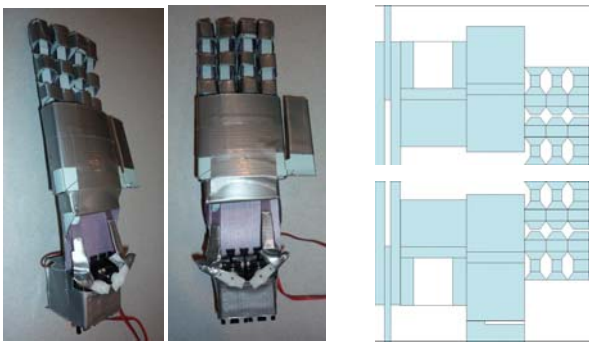


Fig.10 EMG-to-Motion discrimination for Rock-Scissors-Paper Prosthetic Hand.
*1 The state-motion look-up table is pre-determined after analyzing EMG signals during rock-scissors-paper.
*2 The motor action look-up table is pre-determined for presenting rock, scissors, and paper with the robot hand.



(b)

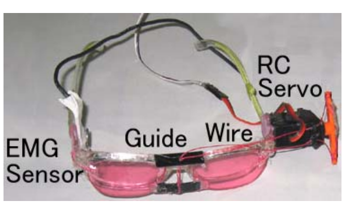
Fig9. Design of Rock-Scissors-Paper Prosthetic Hand. (a) Toy-based development. (b) Printed (paper) sticker based development.

C. A Creative Prosthetic Applications

So far, we mimicked conventional prosthetic hands to introduce recent technology clearly. Meanwhile in this section, we propose the way to design creative prosthetic applications by focusing on relationships between human habit and action.

For examples, presbyopic persons have a difficulty in focusing a close object, and they bend their brows at the time. Then, they require presbyopia spectacles. In short, the habit "bending one's brow" is a trigger to require the action "presbyopia spectacles" (Fig.11a). Therefore, we built the "EMG presbyopia spectacles" (Fig.11b). The EMG sensor is attached on the temple to measures the EMG signal for bending one's brows, and the amplitude of the signal determines the angle of the EMG glasses.

Thus, such a human-machine coupled system is a prospective device and, we believe, there are lots of possibility to design more useful tools for daily life. Therefore, we provide robotic educational courses to discuss and design such new prosthetic applications.



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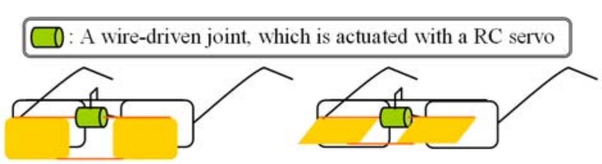

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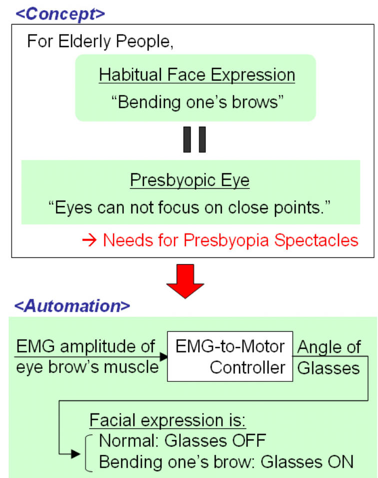

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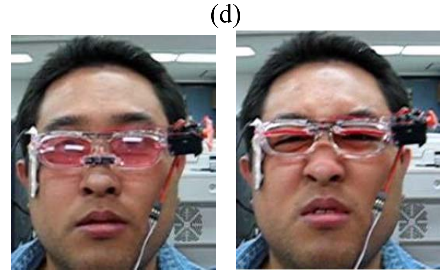


(e) (f)

Fig.11 EMG presbyopia spectacles. (a) Appearance. (b) Glasses are in close. (c) Glasses are in open. (d) Conceptual flowchart for designing prosthetic applocations. (e) Normal facial expression. An EMG sensor is attached on muscles for bending my brows. (f) Facial expression that bends my brow.

IV. EDUCATIONAL COURSES

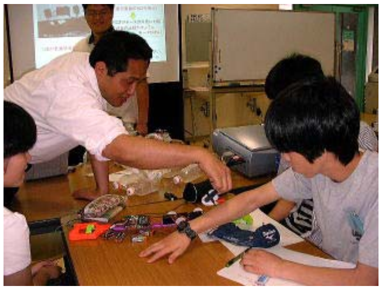
We have conducted robotics educational course for junior high and high school students. Depends on the teaching target, we modify contents and achieves 2-hour-lecture to 3-hour-developmental course. Fig.12 to Fig.13 shows the working scenes.

Table 5 Time to build and Material price list of demonstration kits

	Contents	Duration
1	EMG Sensor: Explanation and Observing own EMG	30 [min]
2	EMG-to-Motor Controller: Operating a motor with your EMG	15 [min]
3	Development of a Robot Hand: Reproduction of the demonstration hand	60 [min]
4	Rock-Scissors-Paper Algorithm: Parameter tuning for EMG-to-Motion discrimination	45 [min]
5	Plying Rock-Scissors-Paper with two prosthetic hands	30 [min]

Table 5 describes the contents of the 3-hour educational course: (1) The EMG is explained by observing participants' own EMG signal; (2) Based on (1), the participants control a

RC-servo as their muscle, and signal transformation on the circuit is displayed with oscilloscopes for helping to understand; (3) The participants split apart the Rock-Scissors-Paper Prosthetic Hand (for demonstration), and produce their Rock-Scissors-Paper prosthetic hand by mimicking the structure; (4) EMG-to-Motion discrimination is explained thought demonstration. We also show our sample codes, and teach how to tune the parameters; (5) Eventually, by using two Rock-Scissors-Paper Prosthetic Hands, the participants play Rock-Scissors-Paper.



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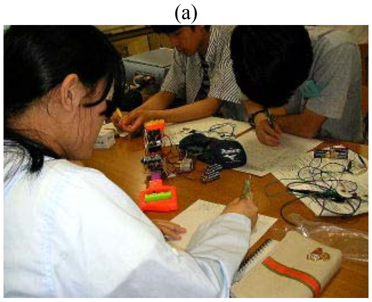
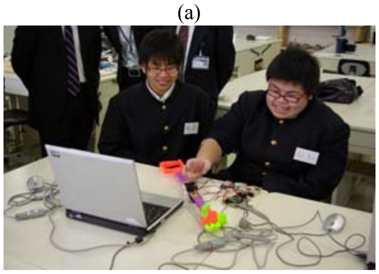


(b)

Fig.12 2-hour lecture for junior and high school students (20 participants).

(a)



(b)

Fig.13 4-hour development course for 3 high school students. (a) Observing own EMG signal. (b) Controlling the Rock-Scissors-Paper Prosthetic Hand, which is built by participants.

V. CONCLUSION

We designed a creative and cheap robotic developmental kit for teaching EMG prosthetic applications: the developmental kit consists of an EMG sensor, an EMG-to-Motor controller, and a wire-driven device. Then, we have already conducted two educational robotic courses for junior high and high school students for the purpose of encouraging participants' interest to science and technology and gain understanding knowledge on both engineering aspect and biology aspect. The hand-made EMG sensor proved that even junior high school students are able to build it (cheap). The EMG-to-Motor controller enabled participants to control a RC motor as their muscle, and we also deliver that it helps to design new simple and cheap prosthetic applications based on participants' own ideas (creativity).

Moreover, we provided three demonstrations of prosthetic applications: (1) Simple Prosthetic Hand is a mimic of commercial prosthetic hand. It represents that low-precise design is enough to realize prosthetic functions so that it is good for learning beginners' development. (2) Rock-Scissors-Paper Prosthetic Hand is based on prosthetic hands for research use. It clearly delivers EMG-to-Motion discrimination. (3) EMG Presbyopia Spectacles represents designing creative prosthetic applications with our proposed developmental kit. Finally, we have confirmed that junior high and high school students enjoyed the demonstrations and understood how prosthetic hands work.

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