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bioToys: biofeedback device for physiotherapy using building blocks

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Abstract: In the field of physiotherapy for children with impaired motor functions or congenital loss of limbs, physical therapists (PT) assist children to recover motor functions or to adapt to the use of artificial limbs controlled by Electromyography. However, children easily give up training to use artificial limbs because it becomes rapidly boring. Also, PT are required to perform many operations on the biofeedback system. It is important for children to feel excited about therapeutic activities and the system used should be easy to handled by the PT. In this research, we propose a building block based biofeedback toys called "*bioToys*". This system enables the use of biological or physiological signals in input blocks and generates various outputs. This building block system also allows users to program biofeedback systems. We show that the developed system is capable to control toys and to record muscle activities in real time.

Keywords: Playware, biofeedback, Tangible User Interfaces, toy, children, education.

1 INTRODUCTION

Electromyography (EMG) biofeedback is one of the methods of physiotherapy for augmented motor function [1]. EMG biofeedback therapy is widely used in the training for patient with impaired motor function or congenital loss of limbs. Physical therapists (PT) assist patient to recover the motor function and several biofeedback devices have been proposed so far such as presenting a waveform on the LCD display (i.e. MyoBoy, Ottobock, Inc.), converting EMG to the sound tone [2], or displaying the shape and brightness on the specific muscle on the body skin [3]. Also, these treatments are used for the training of EMG prosthesis. Although the rehabilitation trainings generally consist of simple tasks such as picking up and moving small objects,, some adults patients endure this training because of their strong motivation to go back to their daily life. However, children often refuse the training because it becomes boring after a while or become they just dislike it. Also, biofeedback systems require the PT to perform many operations including setting of instrumentation, parameters tuning, and maintenance of prosthesis. In addition, it is needed to observe the patient's activity, check the output from the biofeedback system, and instruct the patient the next action to be performed all at the same time. Then, it is also important for children to feel excited with the therapeutic activities to keep their motivation and this causes strong affects the therapeutic achievements. Since the therapist needs to handle the system and paid less attention to the therapeutic activity itself and also it is difficult to observe the child activity while handling the system.

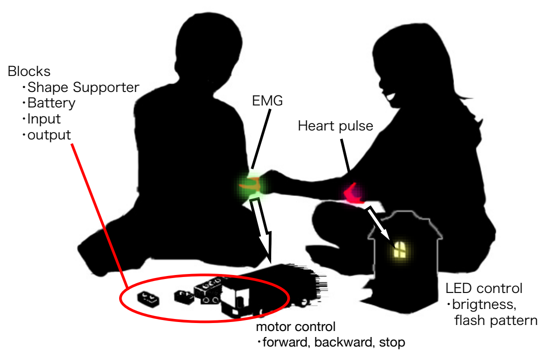

Fig. 1. Concept of bioToys

Many works have reported about the benefit of tangible user interfaces [4] which offer educational benefits to children. Especially, building blocks system have been a proposed as a tool for learning programing language [5,6,7]. These building blocks systems allows user to freely build system, and the system produces outcome under the combination of properly built blocks with a particular function. We consider that building blocks systems are an effective education tool for children to learn about system procedure, and also could encourage child to learn in voluntary and creative manners. .

In this study, we first introduce a building blocks like biofeedback toys called "bioToys" as shown in Fig.1 . Promising applications include a creative tool for physiotherapy. In this application, this system is designed for users to understand the causality between biosignal and system

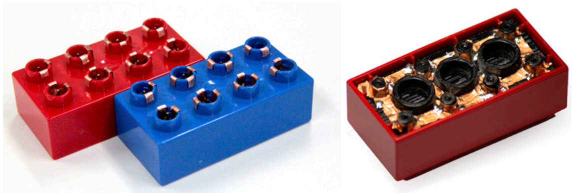

Fig. 2. Overview of the developed blocks.

output in an intuitive manner, and could encourages children to self initiate playing and training. Also it is easy for the PT and children to handle it.

2 BUILDING BLOCKS SYSTEM

2.1 Device Specification

Figure 2 shows an overview of the developed blocks. We implemented the system on the DUPLO(LEGO Group) and four types of block devices are constructed such as shape supporter, battery, input and output. These block-type devices are modified from the normal blocks and are added two connectors. On the upper side, each connecting parts has two electrodes. The inner and outer pins are used as a power and ground lines, respectively. On the lower side, in opposite, the connecting hole is used as a ground and the outer as a power. Since these electrodes are designed like coaxial socket, the devices shape are almost the same as the one of normal blocks and they can connect not only to modified block devices but also to regular DUPLO® blocks in a traditional way.

On the proposed system, power to each block is provided by a single master supply from the battery block. Recharging only the battery block is therefore adequate for maintenance. In order to reduce the number of cables between the blocks and also increase the flexibility of the system, power line communications have been used to share information between the blocks. Therefore, although the developed blocks have an electrical connection and function, physical connection between blocks are not limited. This mechanism allows the user to use and handle the developed blocks in the same way as normal building blocks.

Table 1 shows an example of block types and their functions. The developed blocks are classified in four different types. (i) *Link Block* is used to connect or disconnect the circuit and also used to determine the physical shape. Normal blocks are used to create shapes and separate electrical connections between blocks. Bridge blocks are used not only to create the shape but also to provide electrical connectivity and data communication between blocks through the in-built circuit between the upper and lower side. (ii) *Processing block* equipped with an electronic circuit with microcontroller (LPC1113/302, NXP) has different functions. These blocks are performed to obtain and transmit data to other blocks. Wireless receiver block is implemented to obtain biosignal or physical motion data form the wearable sensor via Bluetooth connection. Since biosignals and human motions are measured on body skin, each receiver block is paired with a wearable sensor. It then receives those messages from a pair of signal processing block and broadcasts to other blocks in the network. Parameter Tuner block has a gain adjuster for tuning data for the output. (iv) *Action Blocks* interpret the message from other blocks and convert the signal for providing several actions such as motion, vibrations, sounds and illuminations.

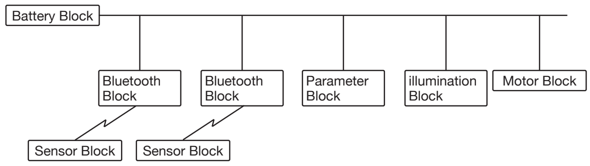

Fig. 3. Network structure of blocks

2.2 System Configuration

Figure 3 shows an example of a network structure between the connected blocks. Note that data communication is solely done on a power line. This network topology is a bus-network. When the battery block is switched on, blocks connected to the power line start to work according to their functions. Any blocks connected to the network broadcast data and share the circuit by serial communication. These data consist of a header, data length, its own specific type, signal data value/command and CRC. To avoid conflicts or

Table. 1. Example of the block type

Category	Specific type	Functions
Link Block	Normal	Disconnection between blocks
	Bridge	Connection between blocks
Power Block	Battery	Supply voltage to the blocks and monitoring power line
Processing Block	Signal Processing	AD conversion, processing of sensor signal and transmitting to received block
	Wireless Reciever	Receiving data from sensor and transmitting data to power line
	Parameter Tuner	AD conversion of a volume voltage and transmitting data to power line
Action Block	Motor	Get data form power line and interpret the data then gen-erate output for driving each element
	LEDs	
	Sound	

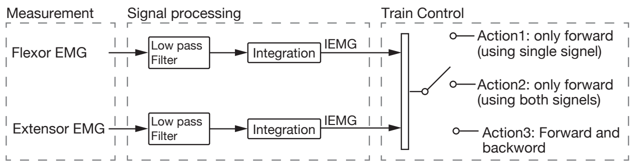

Fig. 4. Train system flow

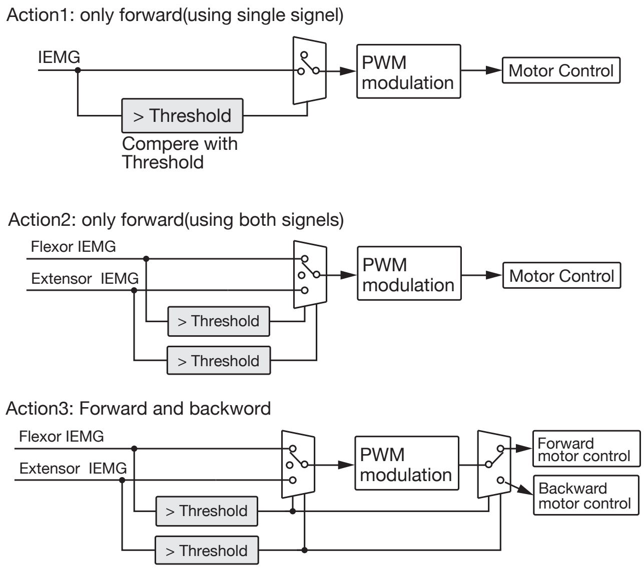

Fig. 5. variations of the train action

a crunch of the bandwidth, signal processing blocks compute AD converting data to meaningful and low frequency data depending on measurement signal feature before transmission. For example, EMG signals are obtained from the electrodes attached with a human skin and sampled at a rate around 1kHz. The resulting Integrated EMG(IEMG) signals are transmitted at a rate around 100Hz. On the other hand, in the case of changing parameters such as the parameter tuner, a rate of about 10Hz would be sufficient. When action blocks obtain data from the power line, the specific type of these data are checked and processed.

2.3 Action Blocks and Block Assembly

We have developed the train-toy system based on motor action block. Figure 4, 5 and 6 show the system overview and data flow. The train has two kinds of connectors, the connectors placed at the front and back sides on the roof are assigned for forward and backward motor control, respectively.. A set of a battery, block wireless receiver and parameter tuner are assembled to the train on the different side of the roof, the train moves forward or backward according to the given block assembly. In a simple case, when data values are above the given threshold determined by the parameter tuner (Action1). Then, when another block set is added, the train moves forward when either of the data values are above the threshold (Action2)(See Figure 6). On the other hand, when each set of blocks are assembled on each side of the roof, the train moves frontward or backward when either data value are above the threshold (Action3). These biofeedback systems are designed to manipulate blocks by simply arranging and rearranging them without consideration about the block order with the aid of communication on the battery line.

Fig. 6. Overview of the train system

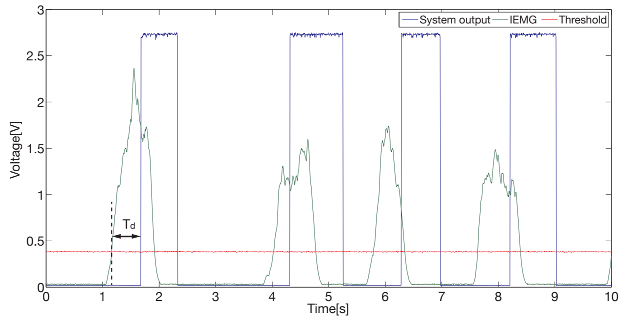

Fig. 7. IEMG, threshold and generated output Waveforms

3 Experiment

3.1 System Evaluation

In order to evaluate the performance of the proposed system, we conduct an evaluation experiment to verify the latency of the system. We prepared a basic system that is composed by a EMG wearable sensor, a wireless receiver, a parameter tuner and an action blocks. In this experiment, the biosignal data are transmitted at 1kHz and the parameter tuner block is transmitted data at 10Hz. Figure 7 shows a scene during the experiment. The train is controlled according to the measured EMG signal attached with the elbow of the subject. We measured T_d[s] is the system latency sixteen times and the averaged result is 0.454s. This includes a time required for wireless communication, and converting power line communication. We consider that this latency does not cause a problem for inferring the causality between bodily action and train movement.

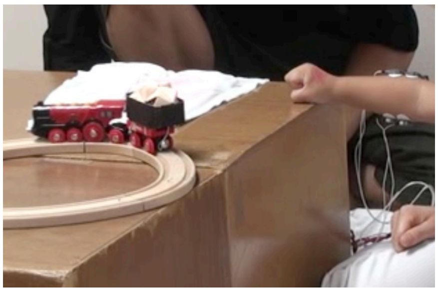

Fig. 8. The scene in the physiotherapy using train system

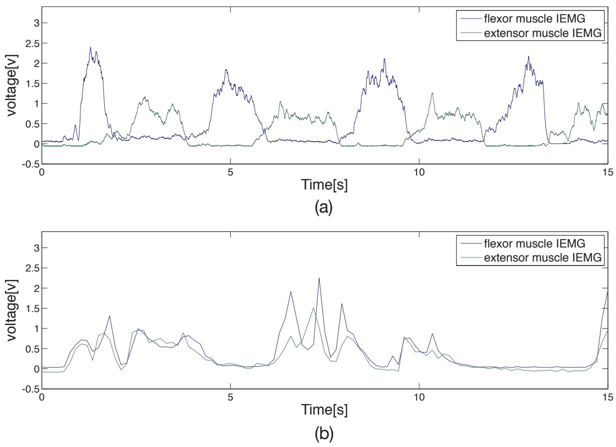

Fig. 9. Flexor and extensor IEMG (a) healthy participant (b) the child with congenital loss of left arm

3.2 Case-Study: Therapeutic Activities for Children

We used the train system with a child suffering from a congenital loss of the left arm.Children with forearm impaired motor functions or a congenital loss of limbs are trained to generate proper EMG signals for the use of prosthesis limb and hand. The participant is being trained to use flexor and extensor muscle for opening and closing the prosthesis hand. We describe such training can be achieved using the proposed biofeedback system. Before this experiment, the participant were not likely to wear cosmetic artificial hand and he was uncooperative even for the EMG measurement.. We then introduced a prototype setup as shown in Figure 8, which shows the scene in therapeutic activity using the train system. We observed that the participant was motivated and willing to play with the train toy. He was more cooperative to have its EMG measured. Physiotherapist attended to the session switched the action mode, and measured the EMG signals.

The proposed system is capable not only to control the train but also to record muscle activities in real time. Figure 9 shows the flexor and extensor IEMG wave form. We asked the participant to move the flexor and extensor muscles in turn during playing with the toys. The train system made the participant realize that he still does not control the two muscles separately. The system showed the possibility to help therapist to monitor the children's physiological activity while playing with toys.

4 CONCLUSIONS

In this paper we proposed a unique biofeedback toys called bioToys based on normal and modified building blocks. In the field of physiotherapy for children, therapists are struggling to design therapeutic programs and methods according to the response of patients. They encounter the problem that some children easily give up training to use prosthesis because such training become boring after a while, since the rehabilitation training contents comprise only simple tasks.

We developed special building blocks that can be used in a traditional way, although they are embedded with a fully functioned electronic circuit. We verified that these blocks can be utilized for a biofeedback training that enables the use of biological or physiological signals in processing blocks and can generates various actions. The system are constructed by arranging and rearranging these building blocks easily in real time. Further investigation will also include the design of different types of blocks.

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