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Development of Adaptive Switch Prototype Using Electromyography (EMG) Signal To Access Keyboard Functions

Abstract: The challenges in building a switch for accessing information and communication technology (ICT) are cost and portability. This experiment aims to build a low-cost prototype of switch using readily available components. Electromyography (EMG) technique was employed to give values to a Bluetooth microcontroller, consequently triggering commands when the value went above the threshold. Confusion matrix was developed to test accuracy and precision. Results showed that accuracy and precision can be enhanced by adjusting the threshold.

I. INTRODUCTION

Unlike severe disabilities, people with mild motor impairment still retain the function of some muscles to a varying degree. Some individuals have limited use of their hands. They can move their arms, but do not have full control of small movements. This makes it difficult to access information and communication technology (ICT) using traditional system. Therefore, mildly impaired people require modified computer access system. An adaptive switch allows individuals to activate ICT commands, such as keyboard and mouse function.

There are several requirements in designing a switch. The major barrier for mild impaired people to access this technology is affordability. Most people with disabilities have limited financial resources [1]. Other factor includes portability. The device should be simple and small enough to be carried around without attracting unnecessary attention.

Taking these considerations, a Bluetooth enabled device using existing components was developed. Bluetooth does not require wiring and consumes low power. Without having to manufacture the components, small enterprises can build the device, thus increasing the availability in the market. Muscle activity can be recorded using electromyography (EMG) and transferred into a microcontroller to enable keyboard function. Surface EMG was used because it is non-invasive. This report aims to design a prototype of such device, which will be referred as bionic clicker. The device employed MyoWare Muscle Sensor as input and Adafruit Feather 32u4 Bluefruit as microcontroller. Furthermore, performance test result is conducted to assess the accuracy and precision. Results from this report serve to understand the basic components that are needed in building a simple switch.

II. METHODS

Two parts made up the sensor assembly: MyoWare Muscle Sensor and MyoWare Power Shield. The goal was to put the two parts together so the sensor got its supply of power from coin cell batteries placed inside the power shield. This was done by cutting two rows of three female pin headers. One row was attached into the RAW, SHID, and GND holes on the sensor, and the other row into the +, -, and SIG holes. They were secured by soldering on the back side of the sensor. For the power shield, two rows of three male pin headers were soldered on both sides of the power shield: +VS, GND, SIG holes, and RAW, SHLD, GND holes. Two CR2032 lithium batteries were placed on the power shield and electrode pads are placed on the sensor. Finally, sensor and power shield were attached together.

Recording of EMG was carried out by coupling an oscilloscope probe, each to channel A and B of PicoScope® 2000 Series. SIG and RAW signals will be compared, to determine which signal can be used to set a threshold. Probe A was assigned to the SIG pin of MyoWare Muscle Sensor, and probe B was assigned to the RAW pin. Next, a ground lead with alligator clip was used to attach both probes to GND reference on the sensor, using a jumper wire as the connector. Electrode pads were placed on outside forearm muscle and the reference pad on the bony region of elbow. PicoLog software was used to display and record oscilloscope data.

To simulate different conditions, four scenarios were developed, each consist of 20 cycles.

Table 2.1. Scenarios simulating different conditions of human activity.

Scenario	Description
A	1 second contraction, 1 second rest
B	1 second contraction, 5 second rest
C	5 second contraction, 1 second rest
D	5 second contraction, 5 second rest

In designing control circuit, 16 rows of male pin headers were attached to the corresponding 16 rows of hole on the Adafruit Feather 32u4 Bluefruit. Another 12 rows were attached to the other side. The Bluetooth board was tested by commanding it to print “BOOM”. The test worked well with a Mac laptop. The output could also be seen on Serial Monitor tool in the Arduino software.

Assembling the sensor and Bluetooth board together was done by placing a jumper wire from SIG end of sensor to A0 end of board and another wire from GND end of sensor to GND end of board (Fig 2.1). The resulting bionic clicker was tested (Fig 2.2) by analogRead function, which read the input on analog pin A0.

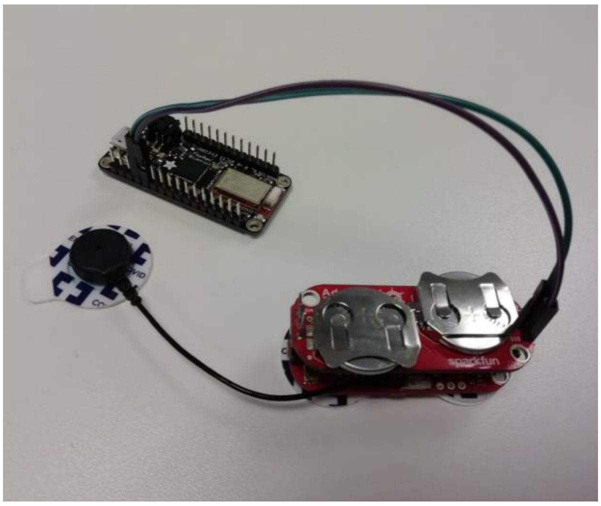


Fig 2.1. A complete setup of bionic clicker consisted of sensor assembly and microcontroller.

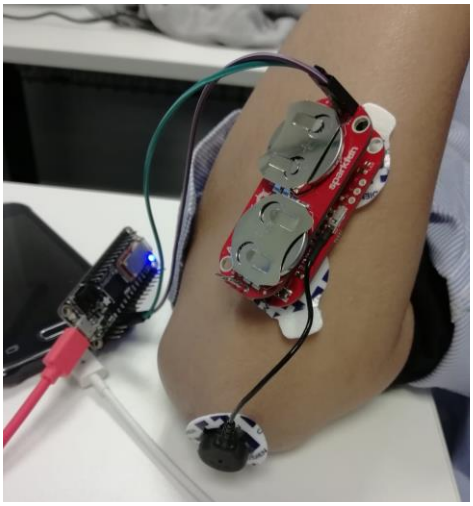


Fig 2.2. Placement of bionic clicker on the outside forearm.

Threshold was defined as the minimum value to trigger a command. From the previous step involving different scenarios, a threshold of 200 was decided. Further explanation will be discussed in chapter III. Device evaluation was performed using timed contraction as input and word printing as output. Short contraction (less than 1 second) would print “SHORT” and long contraction (more than 1 second) would print “LONG”. Five different conditions were developed:

1. Short contraction with 5 second interval (20 cycles)
2. Long contraction with 5 second interval (20 cycles)
3. Other muscle movement (20 cycles)
4. No movement (20 cycles)
5. Short contraction, long contraction, and other muscle movement with 5 second interval between each action (10 cycles)

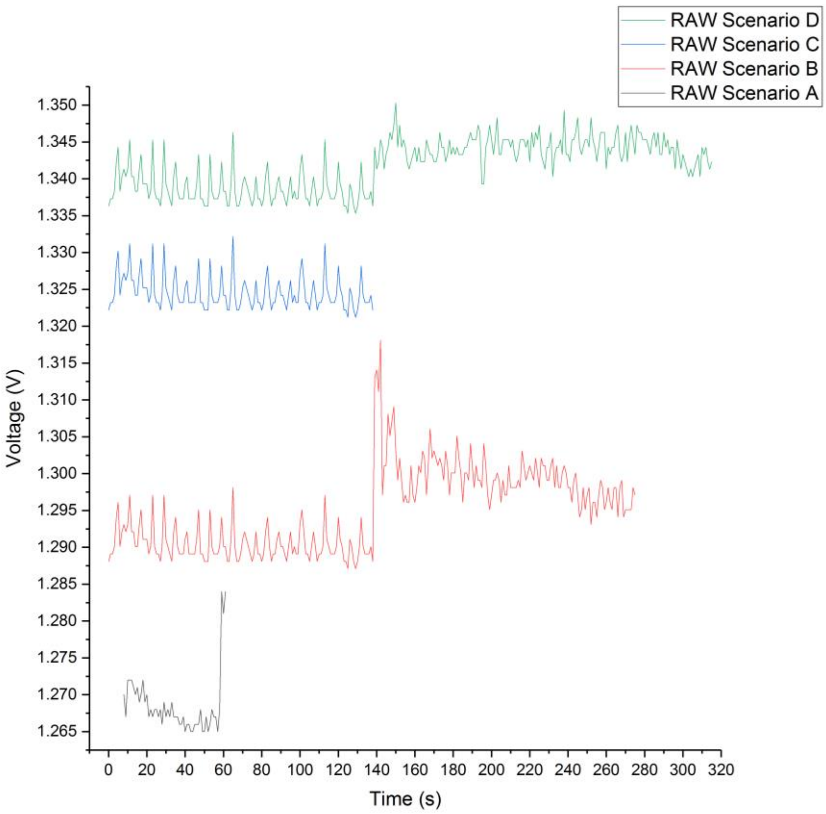
The conditions were replicated with different thresholds; 20% increase and 20% decrease from the original threshold.

III. RESULTS AND DISCUSSION

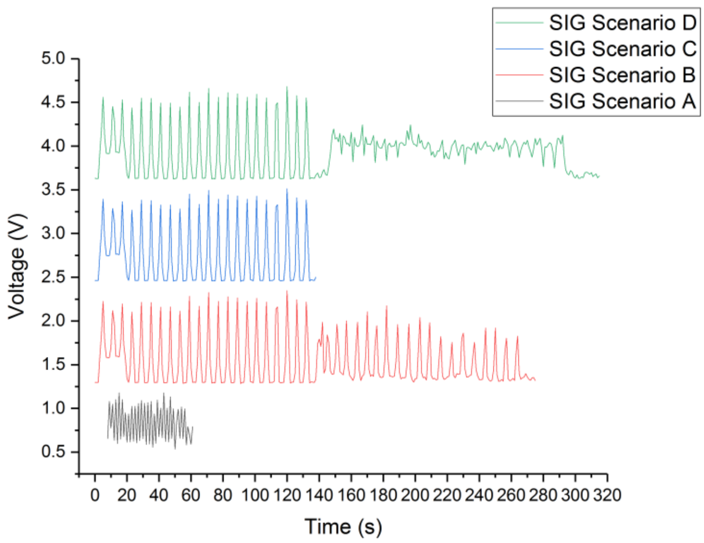
In choosing the useful muscle as control input, there should be no interference from other muscle and the continuous contraction shall not exhaust the person. Placing electrodes on upper limb is the most feasible option, because it is easy to control and does not attract attention. Therefore, we used muscle on the forearm because the values are stable compared to fingers and require relatively less force than biceps. Electrodes were placed laterally on the outside forearm so it was aligned with muscle fibers. Reference electrode was fixed on the bony region of elbow. Placing electrode on the middle of muscle belly would produce relatively high motor units [2].

In analyzing EMG activity, we compared signals from RAW and SIG. RAW signal showed higher values and lower amplitude than SIG (Figure 3.1 (a) and (b)). There was little distinction between contraction and rest values. Signal appeared as zig-zag line because it picks up a collection of action potentials from various muscle fibers underneath the electrode. Different muscle fibers fire at different times, so the number oscillates between negative and positive over time [3]. This is more emphasized in surface EMG since the area of electrode is big. The result presented here were all positive because of adjustment in PicoLog. Reason why the values were bigger than SIG may be due to the sensor not calibrated. According to MyoWare data sheet, raw signal should be centered about +Vs/2, which is in line with SIG. Due to time limitation, the data pre. Further calibration needs to be done to explain this irregularity.

SIG was able to capture difference in value of contraction and rest, so it was useful in setting thresholds. This signal was the result of raw signal being filtered, rectified, and integrated so the curve became smooth. Large amplitude of the resulting curve implied amplification took place.



(a)



(b)

Figure 3.1. EMG output for (a) RAW showed no significant difference between contraction and rest phase, whereas (b) SIG showed significant difference, making it useful for setting threshold.

Table 3.1 shows only SIG result, because RAW result could not be used in determining threshold. Minimum contraction value was observed in Scenario D. This was expected because the user had to contract for five seconds, and although rest was five seconds, user had already performed previous scenarios. This value was determined as the threshold, because it reflects real-life situation where user may experience fatigue. User should not exert too much force to activate the device.

MyoWare sensor delivers analog signal to Bluetooth module. The module is embedded with Analog-to-Digital Converter (ADC), which converts analog input in voltage to digital output of integers between 0 and 1023 [4]. The supply voltage was between 0 and 3.3 V. Therefore, 0.648873 V would show as ~200 in the module. This was further proved when calibrating the device.

Table 3.1. Means and standard deviations of contraction and rest phases were collected from four different scenarios: A is one second contraction followed by one second rest; B is one second contraction and five second rest; C is five second contraction and one second rest; and D is five second contraction and five second rest. Measurements are in volts.

Scenario	Value at Rest (V)	Value at Contraction (V)
A	0.5853 (±0.077856)	0.907682 (±0.211923)
B	0.260094 (±0.143166)	0.921279 (±0.163445)
C	0.230346 (±0.134677)	0.881971 (±0.245043)
D	0.270907 (±0.136693)	0.648873 (±0.19747)

Increasing the functionality of bionic clicker can be achieved by various means, including adjusting the time of contraction, number of contraction, or combination of those. Accordingly, short and long contraction were selected as inputs because it requires less energy than having to contract two or several times.

Confusion matrix was used to assess accuracy and precision of the device. Accuracy gives the idea of how often the result is correct. Precision shows how often the result predicted correctly is correct [5]. Therefore, accuracy is the ratio of all correct prediction (True Positive + True Negative) to total predictions. Precision is the ratio of True Positive to the sum of True Positive and False Positive.

Five conditions were subjected to user as stated in chapter II. If short contraction is expected and it shows “SHORT”, it is True Positive. If it shows “LONG”, it is False Positive. If it shows nothing, it is False Negative. The similar concept also applies if long contraction is expected. If no movement is expected and it shows nothing, it is True Negative. If it shows either “SHORT” or “LONG”, it becomes False Positive. Other movement also follows similar concept.

Table 3.2. Confusion matrix for different thresholds.

THRESHOLD = 200		
n=110	Predicted: NO	Predicted: YES
Actual: NO	45	17
Actual: YES		48

(a)

THRESHOLD = 240		
n=110	Predicted: NO	Predicted: YES
Actual: NO	44	18
Actual: YES	9	39

(b)

THRESHOLD = 160		
n=110	Predicted: NO	Predicted: YES
Actual: NO	42	17
Actual: YES		51

(c)

TRUE POSITIVE
FALSE NEGATIVE
FALSE POSITIVE
TRUE NEGATIVE

Table 3.3. Accuracy and precision of the device for different thresholds. Accuracy is defined as the true predictions out of all predictions. Precision is defined as the true positive out of all positive predictions.

Threshold	Accuracy	Precision
160	0.8454545	0.75
200	0.8454545	0.7384615
240	0.7545455	0.6842105

Generally, the result showed that lower threshold delivers higher accuracy and precision. Accuracy values of 160 equals to that of 200, but the precision was higher. Precision is a useful tool to quantify how ‘correct’ the device is in specifying a command. User does not want the device to send the wrong command or send a command when he or she does not want to. In other words, false positives should be as small as possible. Therefore, threshold=160 was actually more useful.

IV. CONCLUSION

This paper demonstrated that developing an adaptive switch with accuracy of 0.845 and precision of 0.75 could be achieved using components available on the market. Using confusion matrix allowed us to quantify the device’s performance in different conditions, which was useful in determining a good threshold. Therefore, results from this experiment can be used as a framework to build an adaptive switch with higher accuracy and precision. Limitations of this prototype included USB cable to power the device and limited functionality. It is recommended for further research to add more predictions into the confusion matrix.

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