International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-6, August 2019

Development of a Wireless Surface Electromyography (sEMG) Signal Acquisition Device for Power-Assisted Wheelchair System

M. H. Muhammad Sidik, S.A. Che Ghani, Mahfodzah M Padzi

Abstract*: Muscle fatigue due to long-term of manual wheelchair propulsion is an issue faced by most of users. A power-assisted wheelchair developed to amplify propulsion force that activated by surface electromyography (sEMG). A sEMG detection wireless device to trigger the assistive system is an advantage to ease installation on user's body and wheelchair which is developed in this study. A device that operated on Arduino Nano processor connected to 2 (two) Myoware sEMG sensors to record muscles electrical potential (EP), recognise the pattern and activate DC motors wirelessly connected through radio frequency. Data monitoring on personal computer and smart phone associated with Bluetooth to store and ease observation on recorded information. Tested on 1 healthy participant by propelling a manual wheelchair on tiled floor. Developed device's performance tested and the result are average sampling rate (33.55 ms) and average reading latency was just 12.38 ms. Compared to wired device, sampling rate is faster by % and reading latency slower by 1.04 %. Result demonstrate that developed wireless device would improve in speed in signal reading and enhancement on reading latency is needed to provide a reliable device for power-assisted system in the future.

***Index Terms*: Surface Electromyography, Radio Frequency, Bluetooth, Arduino, Electrical Potential**

I. INTRODUCTION

For the past decades, researchers has discovered wireless transmission to broadcast information replacing conventional wired method. There are numbers of method to transmit wirelessly between portable devices such as Wireless Fidelity (Wi-Fi), Bluetooth and Infrared. Different type of technologies adopting different protocols based on the purposes of data transmission. For instance, a small portable device (headset, sensors) that has low battery size is suitable for Bluetooth technologies which is required low power consumption and connected directly in short range because of low bandwidth transfer method. Meanwhile Wi-Fi is using high bandwidth that transmitting information faster in short range and suited in network system connecting multiple devices to a router [1].

Revised Manuscript Received on August 30, 2019.
* Correspondence Author
M. H. Muhammad Sidik*, Mechanical Engineering Section, Universiti Kuala Lumpur MFI (UniKL MFI), Bandar Baru Bangi, Malaysia.
S.A. Che Ghani, Faculty of Mechanical Engineering, Universiti Malaysia Pahang, Pekan, Pahang, Malaysia.
Mahfodzah M Padzi, Mechanical Engineering Section, Universiti Kuala Lumpur MFI (UniKL MFI), Bandar Baru Bangi, Malaysia.

Today, the advancement in Internet of Thing (IOT) is supported by Bluetooth connecting peripheral devices to transmit information between processor and sensors such as Arduino Microcontroller and Raspberry Pi. Therefore, changes such as on temperature, motion, humidity, volatile organic compounds (VOCs) and environment parameters can be collected and monitored in comforter and easier ways. Normally, all these sensors requiring a transmitter as a medium to transfer data to central controller and Bluetooth is most suitable instead of Wi-Fi due to low power consumption and transmitting small amounts of data. Arduino Nano board is an open source device developed by Arduino LLC capable of converting analog input into digital output and vice versa from sensors to data monitoring devices. These capability makes Arduino a popular choice among researchers and IOT developers to interact with sensors. Muscle cells generating electrical potential called electromyography (EMG) to signal skeletal muscle to contact and can be recorded by electrode. EMG consist of two types, intramuscular EMG and surface EMG (sEMG) [2]. Intramuscular EMG require needle type electrode to record the signal and require difficult procedure to insert the needle inside the muscle. On the other hands, surface electrode placed on skin above targeted muscle to measure the EMG signal and require less procedure and preparation to place it. That's why sEMG are preferable over intramuscular EMG to obtain information on electrical potential during muscle contraction [3]. Electrical potential range is between -5mV to +5mV and frequency is 10Hz to 500Hz [4]. The sEMG data acquisition device is harmless to human body and it's one of the most reliable signal produced to study human movement desire [5]. Therefore, application of sEMG widely used in treating stroke patients by developing rehabilitation equipment works on user sEMG signal[6]. Recently, development on sEMG-controlled assistive device expanded to ease mobility of disabled by controlling hand prosthesis and electrical wheelchair [7]. Most of the development are in early stage and most of the devices are still connected by wired that would limit the user movement during wearing the devices. Transforming to wireless version is one of the alternative to solve it but wireless connection could cause problems such as reliability (delay and sampling rate) and security [8].The purpose of this paper is to present that wireless version sEMG data acquisition device is reliable in context of data transmitting speed (latency) and sampling rate comparing to wired version. Combination of radio frequency and Bluetooth technologies used to transmit sEMG signal from participant's muscle to DC motor activation and data monitoring device (PC and smart phone).

These findings has important impact on developing wireless sEMG data acquisition for another assistive device by creating reliable proof that has same performance on wired one.

II. MATERIALS

Table. 1 Material list

No	Items	Quantity
1	Arduino Nano Microcontroller	2
2	2.4GHz NRF24L01 transceiver module	2
3	HC-05 Bluetooth Module	1
4	MyoWare Muscle Sensor	2
5	Ag/AgCl disposable electrodes	6
6	Smart phone & PC	1

Table 1 shows list of materials to build wireless sEMG data acquisition Arduino Nano Microcontroller (ANM) is equipped with ATmega328P, weight 7g with dimension of 43.18 mm (length) X 17.78 mm (width) X 10.01 mm (depth) is a perfect processing board for small devices. 2.4 GHz NRF24L01 Transceiver is among fastest data transfer module compatible for Arduino that operate on baud rate up to 2 Mbps and maximum distance range is 60 m.

III. METHODOLOGY

The study can be split into 2 parts, first one is development of a sEMG data acquisition system and second part is wireless connection to integrate data acquisition device with data monitoring devices.

SEMG Data Acquisition System

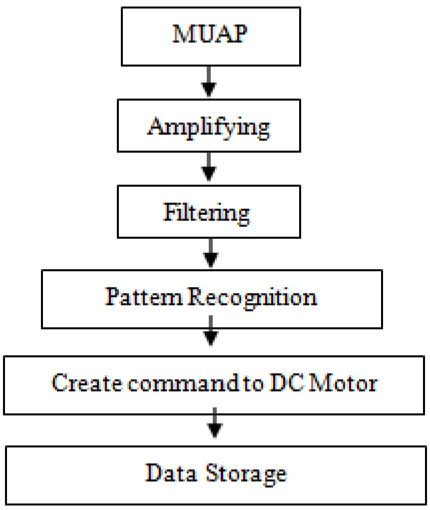
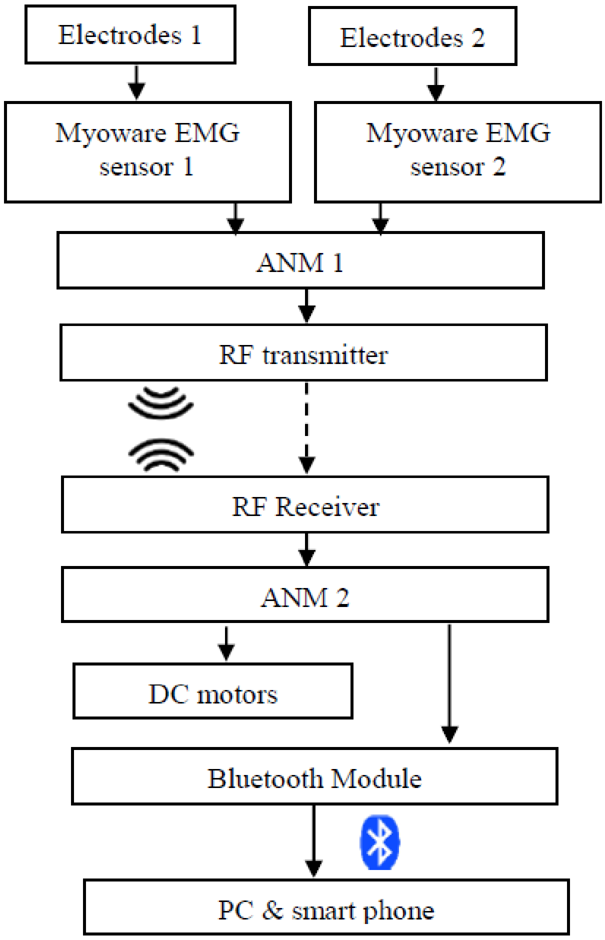


Fig. 1 Schematic representation of sEMG data acquisition system

Muscle was contracted because of electrical potential or Motor Unit Action Potential (MUAP) transmitted by nervous system that can be captured by surface electrodes placed on Biceps Brachii (BIC) and Triceps Brachii (TRI). Made out of Silver/silver chloride (Ag/AgCl) and the advantage of electrode to skin impedance is low compared to other type amplification and filtering process are needed. Myoware muscle sensor board going to complete that process and sending to ANM to convert into analog signal in range 0V to 5V.

The MUAP should be in sinusoidal type of signals but Myoware muscle sensor board rectified by Root Mean Square (RMS) the electric signal because it reflects the physiological activity in the motor unit during contraction [9]. At the same time, signal pattern recognition as per written in algorithm would works to sense if the signal match to pattern, command signal will be sent to DC motors to operate. DC motors keeps rotating as long as receiving command in digital signal "1" from ANM. Since developed system is not integrated yet to DC motors, two (2) LED were used to determine the effectiveness in pattern recognition and command signal generating process. Then, ANM is connected by a cable to PC for data monitoring and to power up all the devices since there are no battery is used. After successfulness of developing and testing wired sEMG data acquisition system, the study proceeds to transform into wireless connection system for data transmission.

A. Wireless SEMG Data Acquisition Device



B.

Fig. 2 Schematic representation of developed wireless Data acquisition device

International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-6, August 2019

Figure 2 shows sEMG data flowchart from collection to monitoring. In wired connection, there is only one ANM is used for signal conversion and pattern recognition. However, problem occurs during makes it most used electrodes in sEMG related researches. MUAP voltages is too low and has signal noise due to movement between electrode and skin, this is where installation onto wheelchair and cause difficulty to users during propulsion if the device remains in wired connection.

Two (2) Arduino Nano microcontrollers were used in wireless version by separating signal conversion and pattern recognition processes into each board. Shortly after converting into analog signal, sEMG data transmitted to second ANM for recognize the pattern and create command to Dc Motors. First ANM is for data conversion wiredly connected to Myoware muscle sensor and second one is pattern recognition. From second ANM, Bluetooth module is used to connect to smart phone and PC for data monitoring to record the data since ANM has low memory space for data restoration.

IV. RESULT

SEMG Data Acquisition System

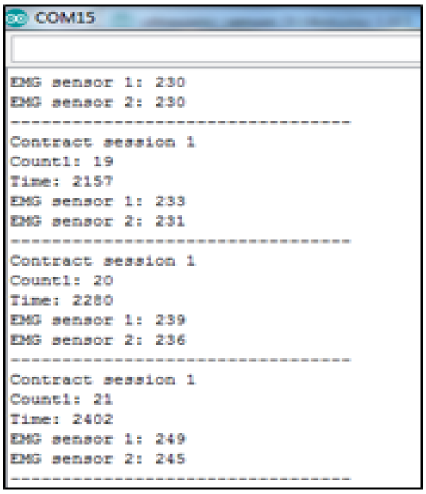


Fig. 3 Information Appeared on PC Sampling Rate (ms)

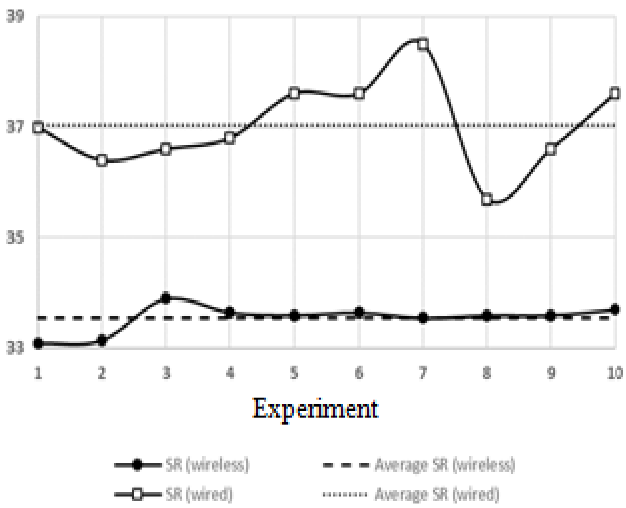


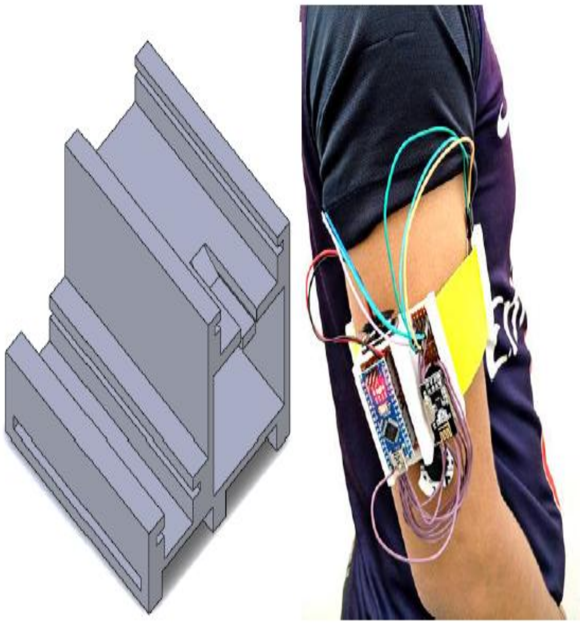
Fig. 4 Result of sampling rate speed for wired and wireless connection

SEMG data processed by ANM and shown in PC Arduino IDE serial monitor all the result that are written as in coding.

There are information such as current phase, counter, time and the sensors value as in figure 3. Additional information on motors condition can be added after developed device integrated with DC motors. Current phase information is important to guide the user to do as per instructed by ANM that can be utilized later in pattern recognition process. Counter to calculate the average value of sEMG signal for each phase and time to inspect either the device working at normal or slower speed. Slower speed affects the sampling rate by failing to record sEMG signal for targeted muscles and reduce the accuracy of the device. Experiments done for ten times to observe developed device's sampling rate and the result as in figure 2. For each experiments, average of sampling rate from 100 reading are taken and calculate the average out of it.

Fastest sampling is in experiment 1 where the speed is 33.1 ms that 1.34% faster than average and slowest (33.9 ms) is 1.04% slower than average recorded in experiment 3. Average speed is 33.55 ms or 29.81 Hz. EMG signal frequency ranges is from 0 to 500 Hz but due to error existed, suggested range is 5 to 450 Hz [10-12] . Average sampling rate for wired is

B. Wireless SEMG Data Acquisition Device



(a) (b)

Fig. 5. (a) CAD design for holder. (b) Strap the device on user's arm

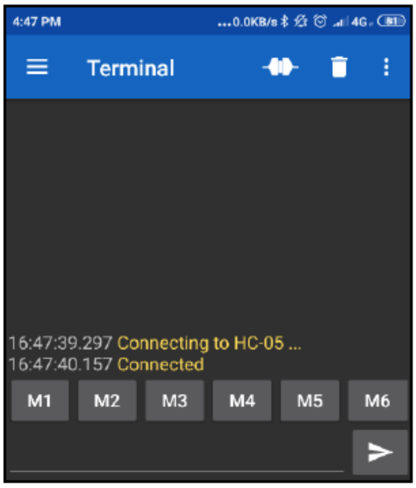


Fig. 6 Connection status between device and smart phone

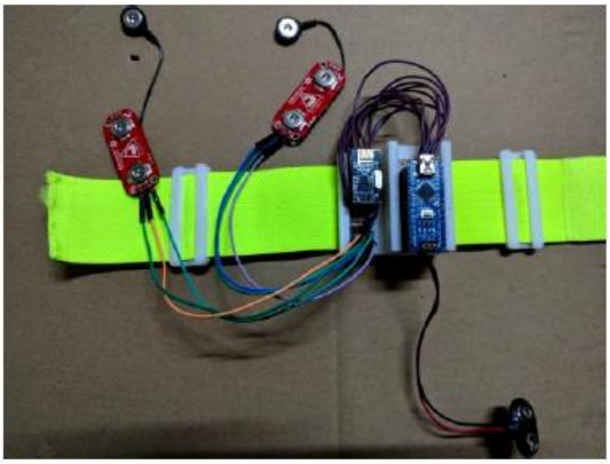


Fig. 7 Developed Devices

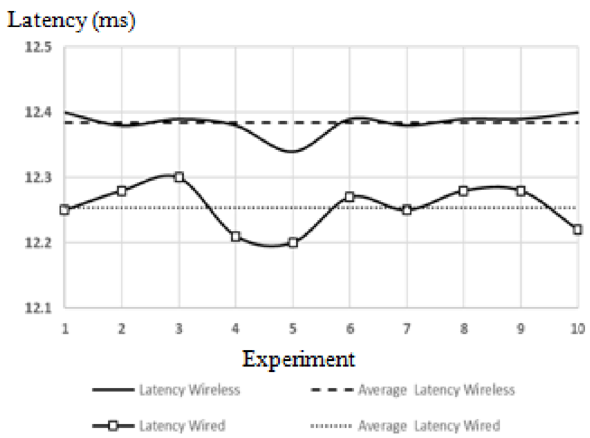


Fig. 8 Result of latency for wired and wireless connection

Developed system are connected by wires and then conversion to wireless version is successfully done. First ANM placed on holder as in Figure 4 sized 54.4mm x 33.0mm x 55.0mm and strapped to user arm as in figure 5. 2.4GHz NRF24L01 transceiver module was used connecting two ANMs to transmit recorded sEMG data that has 250kbps to 2Mbit data transfer rate. Latency for wireless network is one of the reason why most of the device are still in wired condition [13]. Latency is time taken for a command to travel form first ANM (sender) to second ANM (receiver) to process the command. Experiment conducted by sending information (digital signal 1) from first ANM every seconds for 10 seconds and travelling time recorded to receive by second ANM. Distance between both ANMs is 1000 mm and connected by wire and wireless module. Experiments repeated for 10 times and the result as figure 8.

In wired connection, average is 12.26 ms for data to transmit between 2 ANMs. Average wireless transmission latency 12.38 ms for 10 experiments for latency experiment. Lowest latency is in experiment 5 which is 12.34 ms and highest shared between experiment 1 and 10, 12.40 ms. Comparing to wired, wireless transmission latency is slower by 1.04% or 0.12 ms. Latency during data transmitting is lower than sampling shows good sign for system to execute the command send by ANM. The reason is, for an ANM to execute the command, it will happen in the next of reading taken cycle. For example, second ANM would send command to DC motors after recognized the sEMG signal pattern based on previous data.

V. CONCLUSION

This paper proposes a wireless sEMG signal acquisition device to be integrated with power-assist wheelchair that has DC motors as to add up propulsion force. Since the developed device uses wireless communication protocol to send command to power-assist sytem, user's freedom is not limited as compared if they are using wired device. Installation to user's arm is much easier to fasten and the Myoware muscle sensor can be adjusted to make sure the position is correct to extract the data. Location of sensors is important parameter that need to be considered to avoid error by misreading to other muscles [14]. SENIAM guidelines provide information on location to place the sensors to extract data from targeted muscles. There are numerous parameters to obtain better sEMG signal to look into to reduce the error during extracting it.

VI. FUTURE RECOMMENDATION

Enhancement can be made to developed device to improve the performance during data collection. A superior microcontroller or processor such as Raspberry Pi replacing ANM would increase the speed of sampling rate and at the same time reduce the processing time to commands the power-assist system. On top of that, it can upload the data to a server or website so that other persons able to monitor and analyse it for machine learning applications.

ACKNOWLEDGEMENT

This research work was supported by MARA Research and Innovation Fund.

REFERENCES

1. Kellogg, B., et al., PASSIVE WI-FI: Bringing low power to Wi-Fi transmissions. GetMobile: Mobile Computing and Communications, 2017. 20(3): p. 38-41.
2. Farina, D. and F. Negro, Accessing the neural drive to muscle and translation to neurorehabilitation technologies. IEEE Reviews in biomedical engineering, 2012. 5: p. 3-14.
3. Chowdhury, R., et al., Surface electromyography signal processing and classification techniques. Sensors, 2013. 13(9): p. 12431-12466.
4. Al-Mulla, M.R., F. Sepulveda, and M. Colley, Evolved pseudo-wavelet function to optimally decompose sEMG for automated classification of localized muscle fatigue. Medical engineering & physics, 2011. 33(4): p. 411-417.
5. Smoliga, J.M., et al., Reliability and precision of EMG in leg, torso, and arm muscles during running. Journal of Electromyography and Kinesiology, 2010. 20(1): p. e1-e9.
6. Riener, R., T. Nef, and G. Colombo, Robot-aided neurorehabilitation of the upper extremities. Medical and biological engineering and computing, 2005. 43(1): p. 2-10.
7. Podrug, E. and A. Subasi. Surface EMG pattern recognition by using DWT feature extraction and SVM classifier. in The 1st Conference of Medical and Biological Engineering in Bosnia and Herzegovina (CMBEBIH 2015). 2015.
8. Malhotra, R., V. Gupta, and R. Bansal, Simulation & performance analysis of wired and wireless computer networks. Global Journal of Computer Science and Technology, 2011.
9. Fukuda, T.Y., et al., Root mean square value of the electromyographic signal in the isometric torque of the quadriceps, hamstrings and brachial biceps muscles in female subjects. J Appl Res, 2010. 10(1): p. 32-39.
10. Ahamed, M.A., et al. Development of low cost wirelessbiosignal acquisition system for ECG EMG and EOG. In 2015 2nd International Conference on Electrical Information and Communication Technologies (EICT). 2015. IEEE.
11. Merletti, R. and P. Di Torino, Standards for reporting EMG data. J Electromyogr Kinesiol, 1999. 9(1): p. 3-4.
12. Dong-Mei, H., Y. Yi, and W. Zheng. Measurement system for surface electromyogram and handgrip force based on labview. in World Congress on Medical Physics and Biomedical Engineering, September 7-12, 2009, Munich, Germany. 2009. Springer.
13. Zhou, R., et al. Design of a wireless multi-channel surface EMG signal acquisition system. in 2017 3rd IEEE International Conference on Computer and Communications (ICCC). 2017. IEEE.
14. Lopez, R. and T.C. Davies. The effect of surface electromyography placement on muscle activation amplitudes and timing. in 2016 IEEE EMBS International Student Conference (ISC). 2016. IEEE.