MyoWare -Based Muscle Switch for Control, Therapy, and Communication in Individuals with Physical Disabilities

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Abstract

Physically challenged and elderly persons have significant challenges managing their home environment and using electrical appliances and computers. This research suggests a cost-effective wearable muscle-activated switch to aid those with physical disabilities. The muscle-activated switch is created using MyoWare muscle sensors for data collection to determine the activity in the target muscle through Electromyography (EMG) signals and to analyze it for control, gaming therapy, and communication for individuals with physical disabilities. The Arduino facilitates the human and computer interaction and control of things via muscle signals. The BluSMiRF Bluetooth device enables wireless connection in our system, which was developed to help physically challenged individuals use computers and manage home appliances via Wi-Fi switches using Grid-3. This muscle sensor switch's originality lies in its ability to connect with any Bluetooth-compatible device via control by any specific muscle. The system underwent testing on a laptop using Grid-3 software for text-to-speech conversion, speech therapy, and environmental control. Individuals with physical disabilities may choose several modules from the Grid-3 program, including environmental control for managing electrical devices, text-to-speech conversion for Aphasia sufferers, and game treatment.

Keywords: MyoWare Sensor; BluSMiRF Bluetooth; Grid-3; Arduino; Paraplegic Patient

Introduction

Approximately 15% of the global population has various disabilities, affecting an estimated 110 million to 190 million individuals. The source is from an organization in 2011. The human-computer interface is a developing technology that has dramatically improved the quality of life for those with disabilities or injuries, allowing them to do activities independently.

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The human-computer interface is an advancing technology that has significantly enhanced the quality of life for those with impairments or injuries, enabling them to carry out their tasks autonomously (Oskoei & Hu, 2007). Bionic robotics involves implanting robotic devices into the human body to replace lost body parts. These advances in technologies utilize biological signals produced by the human body. Electroencephalogram (EEG) is one of the primary physical signals for operating and controlling assistive devices (Ang & Guan, 2016), Electrooculography (EOG) (Barea et al., 2002), Electromyography (EMG), and Electrocardiography (ECG).

Acquiring an EMG signal might be done invasively with a needle or non-invasively with electrodes positioned on the skin. To maintain individuals comfy as well as closed of damage's method surface-mounted electrodes are typically utilized. Electric signals produced by having muscle mass fibers are referred to as surface area electromyography (sEMG) signals. Electrodes positioned on the external layer of the skin have the ability to notice these electric impulses securely (Merletti & Parker, 2004).

A number of study groups have actually produced sEMG-based gadgets for prosthetic arms arm or leg amputation rehabilitation robotic arm control as well as muscle-based recreation video games (Zhang et al., 2009). The affordable cordless system was produced to collect sEMG coupled with accelerometer information for health care (Biagetti et al., 2018). Spine injuries (SCI) might cause paralysis and also handicap in individuals. In addition, health and wellness problems like strokes can result in muscle mass weak points or an absence of activity in some locations of the body. Taking part in a program for recovery as well as using handy digital devices can aid people do everyday jobs individually (Wiesener et al., 2019).

MyoWare sensing units are easily available for acquisition and are used by numerous research study institutes. Toro et alia showed that MyoWare sensing units can spot tiredness in the muscular tissues (Toro et alia 2019). Khan et alia provided a real-time video game control system that uses EMG information and also a MyoWare gadget to rehab top arm or leg muscle mass (Khan et al., 2019).

Venugopal et al. studied the EMG signals of 7 normal and paralytic patients. They used Arduino UNO with an EMG RKI2401 module to control two relays as "ON" and "OFF" switches via EMG signals (Venugopal et al., 2020). Fadhlannisa & Basari (2020) designed an Electromyography (EMG)--based remote-monitoring system to examine patients more often and provide always-refreshed data. They made use of the surveillance system based upon the Node-MCU compiler, ESP8266

Wi-Fi component, as well as the internet server. The Arm information from an examined person was effectively presented on the internet server-based surveillance system for the speculative examination (Fadhlannisa & Basari, 2020). The low-priced, non-invasive EMG purchase gadget that can recording as well as intensifying EMG signals from 3 surface area EMG electrodes was shown by Huynh(Huynh et al., 2020). The acquired signal was amplified, filtered, rectified, and passed through a low-pass filter. Their design systems demonstrated great accuracy and sensitivity.

Wu et al. took advantage of an affordable Arduino system together with incorporated wearable EMG sensing units. There developed system utilized 3 control formulas: straight, abstract, and also direct discriminant evaluation (LDA) (Wu et al., 2021). Electromyography (EMG) was made use of to examine the physical health and wellness of muscular tissues (Ayaz et al., 2020). Muscle-Sense approach was made use of for approximating the workout work making use of wearable Surface Electromyography (sEMG) sensing units together with regression evaluation. They showed Muscle-Sense's accuracy in work discovering of 0.68 kg (RMSE) making use of forearm plus arm sensing units as well as assistance vector regression (SVR) (Lim et al., 2020).

Muscle mass task throughout workout was determined making use of electromyography (EMG). They use MyoWare muscle mass sensing units with Arduino Uno coupled with Xbee for cordless biceps brachii exhaustion surveillance. They observed that muscle mass fatigue can be fairly determined by determining EMG change rises with a 5-s home window dimension (Suprapto et al., 2023).

This article presents a muscle-based switch with a muscle sensor, an Arduino-based, a power supply, and a Bluetooth module. The goal is to enable persons with physical disabilities to control household appliances using Grid-3 software and Wi-Fi switches on computer and social media platforms.

The next section includes methodology of the proposed muscle sensor system. The proposed approach, system architecture, and components utilized in the muscle sensor system prototype are covered next. The prototype by testing it with Grid-3 and a house model controlled by the muscle sensor prototype are examined in the results section. Outcomes of the investigation are summarized in the conclusion section.

Methods and Materials

Figure 1 depicts the architecture of the proposed system. The muscle sensor acquires data from targeted muscles based on the individual's health. The data is supplied to Arduino, which processes and sends it to Bluetooth. The Bluetooth Mate supports communication via

Bluetooth between an Arduino and the system's CPU, or the laptop enables communication with the Grid-3. The Grid-3 program allows individuals with disabilities to interact, control their surroundings, and use their laptops/tablets. Persons with disabilities can control the room settings via Wi-Fi switches operated by Grid-3 in the solutions. The person receiving medical care can also use social media apps and engage in passions like card-making. The symbol communication tool in Grid-3 may aid those with speech difficulties and can assist them in speech therapy.

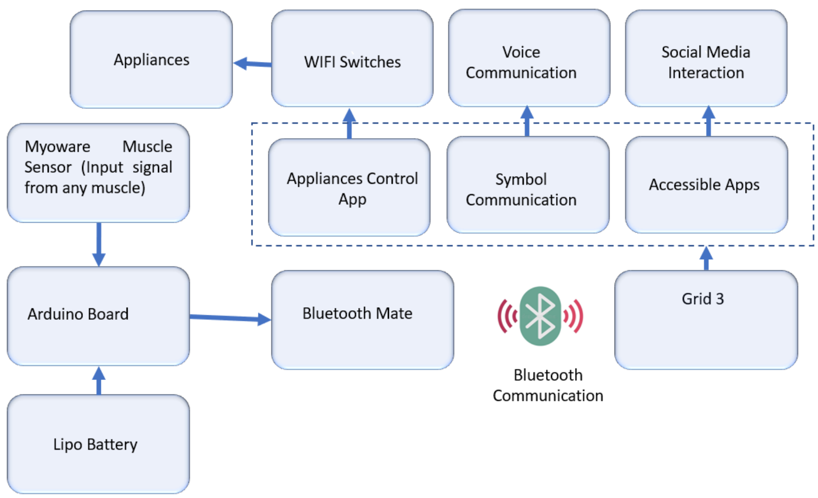

Figure 1: Block Diagram of our proposed model.

The layout of the proposed system is demonstrated in Figure 2. The sensor detects muscle activity by electric potential, commonly referred to as electromyography. The muscle sensor generated an output signal ranging from 0 to Vs Volts, which is directly linked to the activity of the muscles. The sensor detects the potential difference between two electrodes on a specific muscle, turns it into positive voltage using a rectifier, and stabilizes the output. The Electrodes are placed via foam gel on the patient's muscle. The three electrodes of the muscle sensor are used to measure the voltages generated when stretching and contracting, as shown in Figure 2. The magnitude of the voltages represents the intensity of the EMG signal.

In designing our muscle-activated switch, we specifically targeted muscles in the arm region, focusing on key muscle groups responsible for distinct movements and functionalities. The primary muscles under consideration include the biceps, triceps, and forearm flexors/extensors. These muscle masses were chosen based upon their availability and their significance to day-to-day tasks. For example, the arms plus triceps muscles play important duties in joint flexion and also expansion while forearm muscle mass is vital for hand motions as well as grasp stamina. The reasoning behind targeting these certain muscular tissues depends on their capability to supply a varied variety of signals that can be dependably caught via electromyography (EMG).

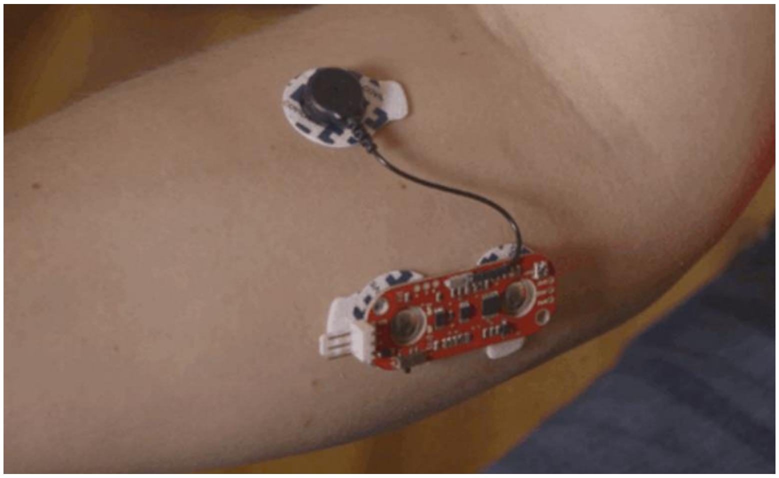

Figure 2: Placing of MyoWare muscle sensor on forearms.

The Arduino Pro Mini is the microcontroller utilized in this model as a result of its small dimension in addition to reduced power intake. The Arduino is the key element of the suggested button system. It tracks the sensors and transmits the signals to the computer through Bluetooth. The SparkFun enables a Bluetooth connection between the muscle sensor and PCs configured as HID Mouse. The Bluetooth mate is employed to control the Bluetooth protocols for connection and transmission with any Bluetooth-enabled device. The Arduino tracks the sensor and transmits the control signals to the PC. The SparkFun Charger/Booster uses a 5V lithium polymer (LiPo) battery to power the whole circuit. The LiPo charger uses a basic booster circuit that increases the Lipo battery's voltage from 3.7V to 5V to provide power to the device at a maximum current of 1A. The charger/booster setup makes our prototype portable.

Grid-3 (developed by SmartBox Assistive Technology) is employed to allows individuals with physical impairments to engage with and manage their surroundings using their desktops, laptops, or iPads. Grid-3 is compatible with multiple options, like eye tracking switch control. We connected the prototype in the switch mode with Grid-3.

System Architecture and Working

Figure 3 illustrates the architecture of our proposed muscle switch. The muscle sensor's signal pin is linked to Pin A_0 on the Arduino. The positive pin of the muscle sensor is attached to the V_{CC} pin, and the negative pin is attached to the ground pin on the Arduino board to power it. The Arduino is connected to the Bluetooth mates, as shown in Figure 3. We used the lithium polymer (LiPo) battery and a SparkFun booster to power the Arduino and the whole system, which assists in the steady operation of the desired switch. This LiPo battery is recharged via a 5-volt charger through a USB wire for multiple uses.

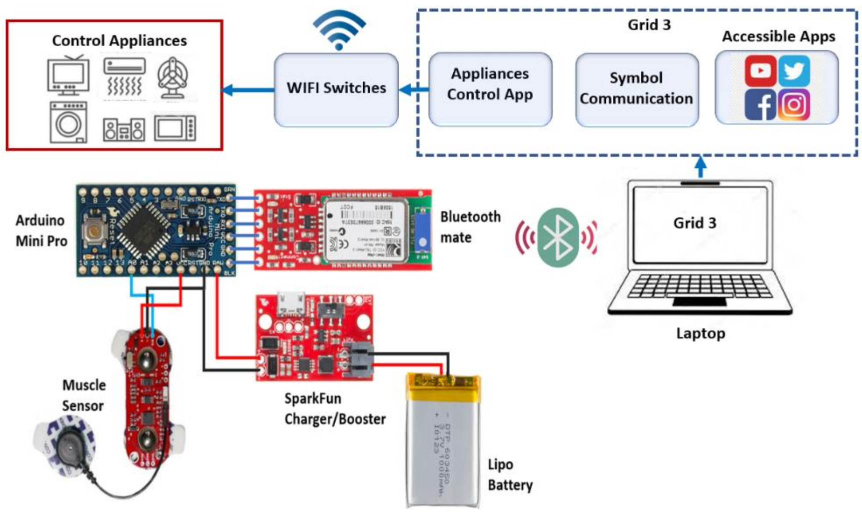

Figure 3: Circuit diagram of the Muscled based switch.

Before connecting the electrodes to the sensor, thoroughly cleaning the particular muscle area is essential. Sensor is placed on the target muscle with one electrode positioned at the center of the muscle while the second electrode is aligned with the muscle. The reference electrode is positioned on a bony part or a nearby unaffected muscle close to the muscle being targeted. The Arduino is attached to the muscle sensor. The red LED on the BluSMiRF module blinks periodically upon turning on the muscle switch to signal that it is prepared to establish a Bluetooth connection. The Bluetooth module may be paired with any device that is Bluetooth-compatible, i.e., a mobile, laptop tablet etc. Once the module is paired and connected, the green LED is illuminated as long as the module is attached.

Ensuring the safety and privacy of users is paramount, especially in a system that involves healthcare data and personal information. Our muscle-activated switch utilizes Bluetooth technology for wireless communication, and robust security measures have been implemented to safeguard user data and maintain privacy. The Bluetooth connection employs advanced encryption protocols, such as AES (Advanced Encryption Standard), to secure the data transmitted between the muscle-activated switch and connected devices. The Bluetooth pairing process incorporates secure authentication mechanisms. Users must undergo a secure pairing procedure to establish a connection, preventing unauthorized devices from accessing the system, which adds an extra layer of security to the communication link. Users are required to undergo authentication processes.

Results and discussion

Figure 4 shows the designed switch linked to Grid-3 in switch mode. Individuals can select their preferred communication or environmental management Grid from the main menu. A signal is sent from the user's muscle to the Grid-3 upon the muscle contraction. The Grid-3 first scans in a vertical direction upon receiving the signal from the muscle contraction as shown in Figure 4, and then scans horizontally scan during the second muscle contraction as shown in Figure 5. On the third signal for muscle contraction, the choice is executed. Figure 6 displays the ecological Grid choices in the main menu. Figure 6 illustrates how the Grid-3 scans in a vertical manner when it receives a signal from a muscular contraction.

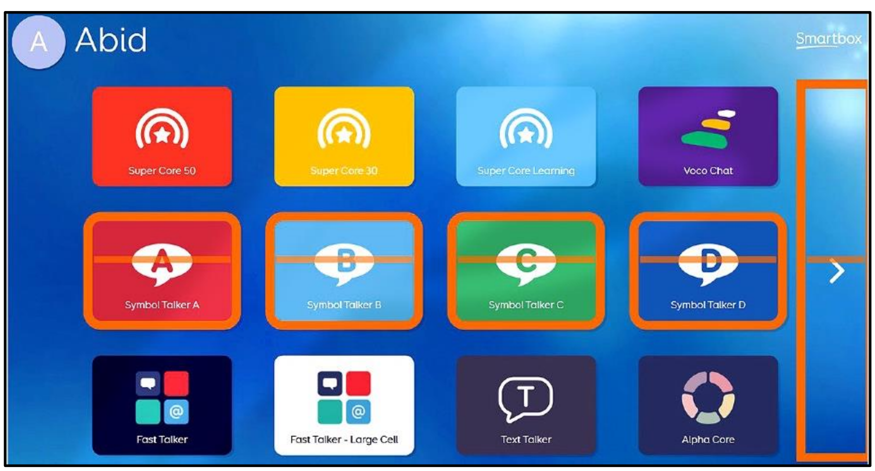

Figure 4: A horizontal scan for selecting a Grid in switch mode.

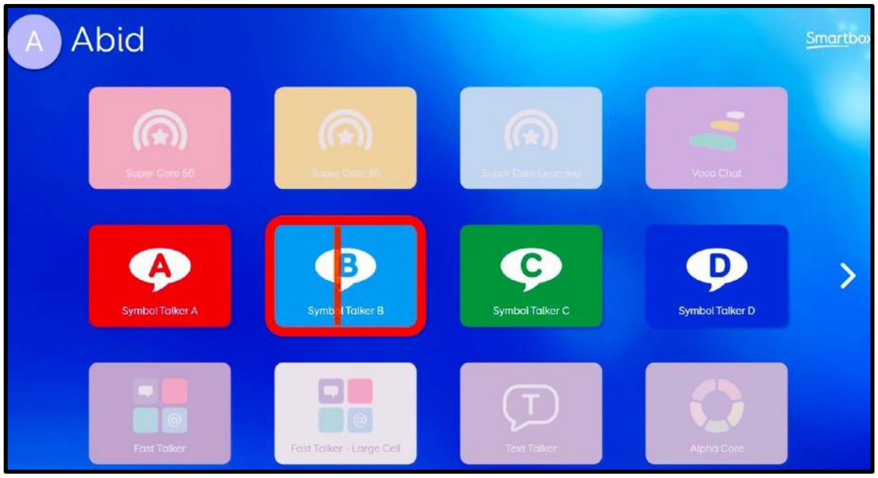

Figure 5: A vertical scan for selecting the Grid in switch mode.

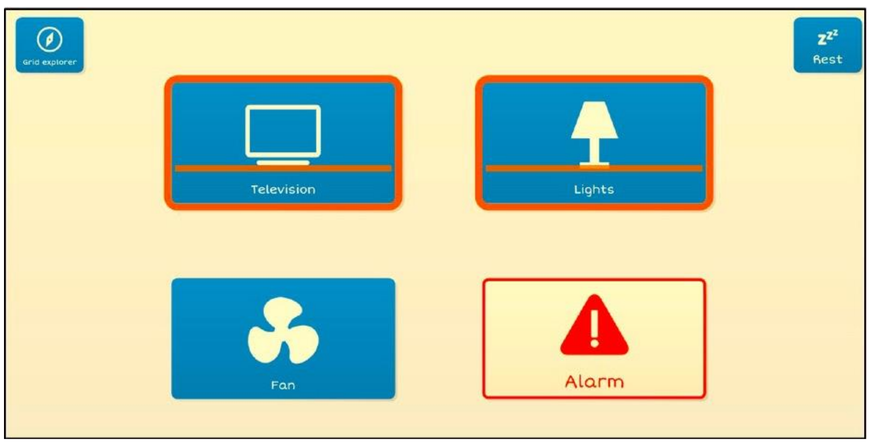

Figure 6: A Horizontal scan in Grid-3 for selecting appliances.

Figure 7 shows how it scans horizontally during a second muscle contraction. The fan, light, and television have been chosen by Grid. Users may choose any Grid using a muscle switch with little effort or movement. The symbol talker Grid selection is shown in Figure 8. It demonstrates the vertical scanning process of the Grid-3 when it detects a signal from a muscle contraction. Figure 9 illustrates the horizontal scanning process that occurs during a subsequent muscle contraction. This module aids those with physical limitations and speech impairments by using a muscle to pick words for communication or expression from a Grid.

Figure 7: A vertical scan in Grid-3 for selecting appliance control.

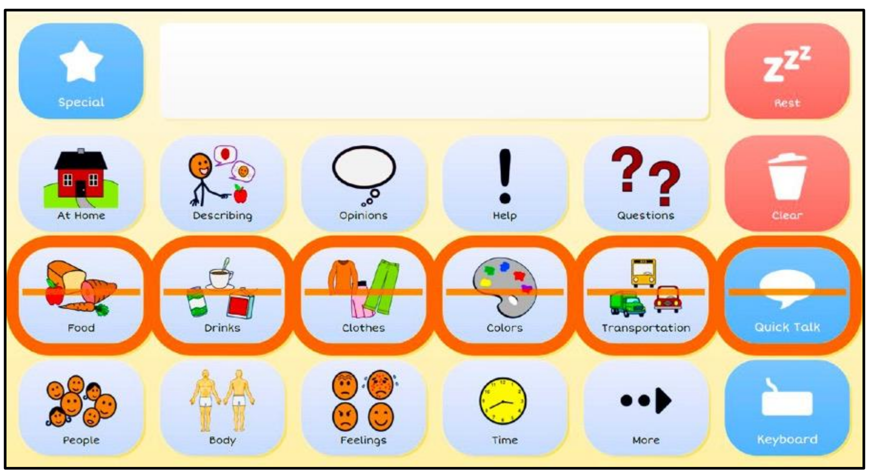

Figure 8: A horizontal scan in Grid-3 to choose a symbol talker.

Figure 10 illustrates a model home environment where patients can use household gadgets by activating specific muscles without moving their bodies. The muscle switch has successfully been connected to the laptop via Bluetooth, as discussed in the above section. The design prototype is economical and compatible with any Bluetooth-enabled device. The prototype is compatible with Grid-3, enabling its use with laptops, android smartphones, or iPads. Several modes could help paraplegic people with restricted motion during gaming therapy, provide speech-to-text conversion for Aphasia patients, provide access to social networking platforms and smartphones, and control the atmosphere around them via wireless switches associated with electrical/electronic devices.

Figure 9: A horizontal scan in Grid-3 to choose a symbol talker.

Grid-3's alarm mode may also alert caretakers or medical personnel during an emergency. Any particular muscle may operate this revolutionary switch, providing an advantage for paraplegic and elderly individuals. It is additionally capable of linking to other devices with Bluetooth support. The use of a lipo battery setup offers users the convenience of portability and wireless communication abilities. The switch design is compatible with devices that feature accessibility mode.

However there are drawbacks to the designed switch. Variations in EMG signals due to variations electrode placement and muscle fatigue can pose challenges with muscle activated switches. To ensure accurate signal recognition by the system these factors need to be considered. Individuals with disabilities may face difficulties adapting to muscle activated switches emphasizing the importance of user comfort, sensitivity optimization and adequate training and support for enhancing user acceptance and usability. Environmental interference with EMG signals could affect the reliability of the muscle activated switch. Electrical noise, electronics and external factors may introduce interference. Implementing noise reduction techniques and ensuring signal robustness across environments will be crucial.

The utilization of Node-MCU, ESP8266 and Bluetooth technology comes with considerations related to data transfer speed, power consumption and connectivity issues. A critical aspect of optimizing the system involves finding a balance between desired performance levels and technical constraints.

Figure 10: Hardware model for home appliances control via muscle sensor.

Conclusion

Science uses sophisticated technology to provide communication alternatives and regulate the environment for people with disabilities. The current research presents a muscle-activated switch based on EMG sensing for wireless control. It is designed for those with physical limitations to manage their surroundings and operate it. The MyoWare muscle sensor, linked to an Arduino board, gathers and processes data from the specific muscle and transmits control signals to the Smart-Grid using a BluSMiRF. Individuals with physical disabilities can use electronic gadgets such as iPads, PCs, and mobile phones using a muscle switch developed to interact with and control their surroundings utilizing

Wi-Fi switches. The designed prototype switch can be helpful in-game therapy for physically challenged persons.

In conclusion, the development and successful implementation of our muscle-activated switch represents a significant stride in assistive technology for individuals with physical disabilities. Future work could focus on refining signal processing algorithms to improve the accuracy and responsiveness of the muscle-activated switch. Expanding the system to integrate signals from multiple muscles could enhance the range and specificity of controlled actions. Considering the growing interest in immersive technologies, integrating the muscle-activated switch with VR or AR applications could open up new possibilities for rehabilitation, gaming therapy, and interactive communication for individuals with physical disabilities.

References:

Ang, K. K., & Guan, C. (2016). EEG-based strategies to detect motor imagery for control and rehabilitation. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, *25*(4), 392-401.

Ayaz, M., Ayub, M. W., & Qureshi, I. A. (2020). Arduino based fatigue level measurement in muscular activity using RMS technique. 2020 International Conference on e-Health and Bioengineering (EHB),

Barea, R., Boquete, L., Mazo, M., & López, E. (2002). Wheelchair guidance strategies using EOG. *Journal of intelligent and robotic systems*, *34*(3), 279-299.

Biagetti, G., Crippa, P., Falaschetti, L., Orcioni, S., & Turchetti, C. (2018). Human activity monitoring system based on wearable sEMG and accelerometer wireless sensor nodes. *Biomedical engineering online*, *17*(1), 1-18.

Fadhlannisa, N. F., & Basari, B. (2020). Design of Wireless Electromyography (EMG) Monitoring System for Muscle Activity Detection on Parkinson Disease. 2020 International Conference on Smart Technology and Applications (ICoSTA),

He, H., & Kiguchi, K. (2007). A study on EMG-based control of exoskeleton robots for human lower-limb motion assist. 2007 6th International Special Topic Conference on Information Technology Applications in Biomedicine,

Huynh, K. Q., Vu, N. T.-H., Bui, N. H., & Pham, H. T.-T. (2020). Building an EMG Receiver System to Control a Peripheral Device. 7th International Conference on the Development of Biomedical Engineering in Vietnam (BME7) Translational Health Science and Technology for Developing Countries, Singapore.

Khan, R. U., Tahir, M. W., & Tiwana, M. I. (2019). Rehabilitation Process of Upper Limbs Muscles through EMG Based Video Game. 2019 International Conference on Robotics and Automation in Industry (ICRAI),

Lim, C. G., Tsai, C. Y., & Chen, M. Y. (2020). Muscle-Sense: Exploring weight sensing using wearable surface electromyography (sEMG). Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction,

Merletti, R., & Parker, P. J. (2004). *Electromyography: physiology, engineering, and non-invasive applications* (Vol. 11). John Wiley & Sons.

Organization, W. H. (2011). World disability report. *World Health Organization, Geneva*.

Oskoei, M. A., & Hu, H. (2007). Myoelectric control systems—A survey. *Biomedical signal processing and control*, *2*(4), 275-294.

Schutta, N. T. (1998). The Impact of Technology on Special Education Students.

Sun, H., Zhang, X., Zhao, Y., Zhang, Y., Zhong, X., & Fan, Z. (2018). A novel feature optimization for wearable human-computer interfaces using surface electromyography sensors. *Sensors*, *18*(3), 869.

Suprapto, S. S., Kusuma, V. A., Farid, M. N., Nursyeha, M. A., Sugiarto, K., Firdaus, A. A., . . . Systems, E. (2023). Gym training muscle fatigue monitoring using EMG MyoWare and arduino with envelope and sliding window methods. *12*(3), 345-350.

Toro, S. F. d., Santos-Cuadros, S., Olmeda, E., Álvarez-Caldas, C., Díaz, V., & San Román, J. L. (2019). Is the Use of a Low-Cost sEMG Sensor Valid to Measure Muscle Fatigue? *Sensors*, *19*(14), 3204.

Venugopal, R. B., Rajalakshmi, T., Suresh, A., & Raj, S. (2020). EMG based signal to control home appliances by partially paralyzed people. 2020 International Conference on Communication and Signal Processing (ICCSP),

Widhiada, W., Parameswara, M., Santhiarsa, I. N., Budiarsa, I., Karohika, I., & Suryawan, I. (2021). HYBRID CONTROL SYSTEM IN BIONIC LEG USING MYOWARE SENSOR. *Journal of Southwest Jiaotong University*, *56*(4).

Wiesener, C., Seel, T., Axelgaard, J., Horton, R., Niedeggen, A., & Schauer, T. (2019). An Inertial Sensor-based Trigger Algorithm for Functional Electrical Stimulation-Assisted Swimming in Paraplegics. *IFAC-PapersOnLine*, *51*(34), 278-283.

Wu, H., Dyson, M., & Nazarpour, K. J. S. (2021). Arduino-based myoelectric control: towards longitudinal study of prosthesis use. *21*(3), 763.

Zhang, X., Chen, X., Wang, W.-h., Yang, J.-h., Lantz, V., & Wang, K.-q. (2009). Hand gesture recognition and virtual game control based on 3D accelerometer and EMG sensors. Proceedings of the 14th international conference on Intelligent user interfaces,