DESDE 2013
https://repository.uaeh.edu.mx/revistas/index.php/icbi/issue/archive
Pädi Boletín Científico de Ciencias Básicas e Ingenierías del ICBI

ISSN: 2007-6363

Publicación Semestral Pädi Vol. 10 No. Especial 5 (2022) 97-102

Wheelchair assistive system with EMG
Sistema de asistencia para sillas de ruedas con EMG

G.R. Peñaloza-Mendoza, V. Becerra-Tapia, C. Vázquez-Barajas, L.M. Carreón-Silva

Departamento de Ingeniería Biomédica, Instituto Tecnológico Superior de Pátzcuaro, 61615, Pátzcuaro, Michoacán, México.

Resumen

En este trabajo de desarrollo tecnológico se presenta el diseño y construcción de un dispositivo que pondrá en funcionamiento un sistema de motores eléctricos para apoyar el movimiento de una silla de ruedas mediante la lectura de señales por medio de un electromiógrafo (EMG) con el fin de detectar el esfuerzo realizado. durante el desplazamiento en una silla de ruedas común, la señal está condicionada de tal forma que detecta únicamente el esfuerzo realizado durante esta acción, al cerrar la mano para sujetar la rueda y accionar la rotación, sin detectar movimientos como simple tensión muscular o brazo normal movimientos Teniendo en cuenta que las personas con discapacidad motora que utilizan silla de ruedas tienen que desplazarse largas distancias y durante todo el día, con este sistema se reduce el esfuerzo y se apoya en caminos con fuertes pendientes al subir.

Palabras Clave: Bioseñales, Electromiografía, Silla de ruedas.

Abstract

In this technological development work, the design and construction of a device is presented which will operate a system of electric motors to support the movement of a wheelchair through the reading of signals by means of an electromyograph (EMG) in order to detect the effort made during displacement in a common wheelchair, the signal is conditioned in such a way that it detects only the effort made during this action, when closing the hand to hold the wheel and drive the rotation, without detecting movements such as simple muscle tension or normal arm movements. Considering that people with motor disabilities who use wheelchairs have to move for long distances and during the whole day, with this system the effort is reduced and it supports on paths with steep slopes when going up.

Keywords: Biosignals, Electromyography, Wheelchair.

1. Introduction

The global action program for people with disabilities establishes prevention, rehabilitation and equal opportunities measures. It is considered that when adopting standard norms in the field of equal opportunities for people with motor disabilities, an architecture and infrastructure must be guaranteed ture that do not limit or discriminate against the population with motor disabilities, thus conditioning public areas with easy access (Instituto, 2016).

Motor disability is the cause of many limitations, which causes a deterioration in the quality of life of the person even when they do not have equal conditions, causes depression, isolation, anxiety in a large percentage of the population in these conditions. Seeking to improve the quality of life of this population, policies are established in which, in addition to adapting the environment, design and engineering are applied, creating devices and vehicles that compensate for the many infrastructure deficiencies that are still present in the cities, and that limit access and mobility.

The adaptation of vehicles is based on the motor disability and the conditions. People with paraplegia, who depend on a wheelchair to get around on a daily basis, but with mobility in their arms, opt for a mechanical wheelchair that allows them to move with the power of their arms, totally independent people make daily routes where it is very common to find obstacles that generate a greater effort such as long slopes, several motorized wheelchairs have been developed and with different technologies that improve the quality of life by eliminating some of the obstacles that limit the movement of these people (Fernández, 2011).

Wheelchairs that work with total human intervention require a lot of effort in the chest and shoulder muscles (Gago, 2010), in addition to the fact that there are several elderly

*Autor para la correspondencia: grey@itspa.edu.mx
Correo electrónico: grey@itspa.edu.mx (Guillermo Rey Peñaloza-Mendoza), vikshelby.500@gmail.com (Víctor Becerra-Tapia), cristhianvazquez425@gmail.com (Cristhian Vázquez-Barajas), lcarreon@itspa.edu.mx (Luis Miguel Carreón-Silva).

Historial del manuscrito: recibido el 27/10/2022, última versión-revisada recibida el 27/10/2022, aceptado el 08/11/2022, publicado el 11/11/2022. **DOI:** https://doi.org/10.29057/icbi.v10iEspecial5.10129

people who do not have enough strength to move independently, requiring the someone else's help.

On the one hand, the complete automation of a wheelchair with motors facilitates movement, but in addition to being expensive, they limit the movement of the muscles, which leads to the chronic development of cardiovascular diseases and the inactivity of the muscles in the area. lumbar, progressively weakening them.

The development of this project supports the human impulse, activating the motor system as soon as the wheel is held and force is applied, allowing the user to move without making a system that makes him dependent (Durán, 2013).

An EMG signal is obtained, which is conditioned in such a way that when making the movement that drives the chair, which is holding, closing the hand and applying the driving force, it generates a sufficient signal that will be conditioned with a development card, for the activation of auxiliary displacement motors.

Normal movements of the arm with little force, even with force tensing the muscles without closing the hand, does not generate a signal that activates the motors, thus ensuring that they are not activated with movements that do not intend to move

2. State of the art

The wheelchair is a solution for the mobility limitations of people with motor disabilities. The first of them contained only mechanical elements that moved when a force was applied, however, with technological advances, the integration of an electronic circuit, electric motors and a gradual handling control was inevitable.

The implementation of electronics allowed to optimize the performance of the motors making them increasingly lighter and more efficient, likewise, it allowed to control the movement through different signals.

Currently, there are multiple research works on the implementation of various control techniques for the movement of wheelchairs, this allows them to be used by people with different motor disabilities. Some technological development works are listed below.

Altamirano and Revilla (2017), present the design and construction of a motorized wheelchair with control based on electroencephalography signals to improve the autonomy of people with motor disabilities at the Lambayeque Regional Hospital, using neural networks. The design, construction and measurement of a wheelchair is shown in Luengo (2011), where it is controlled by means of electronic devices that detect eye movements. In Paredes Robalino (2019), presents the control of the chair through voice commands, the recognized word is transformed into text and interpreted within a graphic interface, this to be used by people with quadriplegics who are not capable of performing the movement. of a joystick.

In the work Küçükyıldız (2015), electromyography-based control of a wheelchair for managing the direction of displacement is explored. Real-time EMG data is processed with the help of MATLAB software. Additionally, a chair-mounted Kinect sensor is implemented to provide safe navigation to the system. Ahmed (2018), presents a technological advance that works in parallel to the wheelchair, this is a robot that can make a person in a wheelchair experience the sensation of standing and navigating while standing, this by applying the electromyography (Figure 1).

3. Materials y methods

3.1 Preliminaries

Superficial electromyography is used clinically to analyze the movements of the muscles, this is due to the ease in placing the electrodes, which is a non-invasive method which also allows us to obtain electrical signals generated by the muscles that are conditioned for use, something very important in this procedure is the placement of the electrodes which will give us impulses from different muscles. In the development of the prototype it is necessary that it be detected only when the hand is closed and force is applied, then the electrodes could be placed as follows. Figure 2 shows the placement of the electrodes for the acquisition of the forearm muscle signal.

3.2 Methodology

Obtaining the signal directly from the electrodes is received by an isolation amplifier that eliminates the physical connection of the user and the instrument to avoid an electric shock. Then the differential amplifier AD620 preamplifies the signal, in the Figure 3 show differential amplifier. The signal generated by muscle has an amplitude of 0 volts (while there is no muscle contraction) and 250 μV during contraction. Because myoelectric signals are of low value, noise or artifacts such as ambient noise or to a greater extent line noise (50Hz – 60Hz) can cause false interpretation of the results. Figure 4 shows a block diagram of the muscle signal processing methodology from acquisition to activation.

<u>Electrical Isolation</u>

Once the signal from the electrodes is obtained, the patient must be electrically separated from the instrumental system, to prevent an unwanted electrical shock from energy leaks or electrical discharges, this is achieved by means of an isolation amplifier circuit, in this case the ISO124P . This is a precision isolation amplifier incorporating a duty cycle modulation-demodulation technique. The signal is transmitted digitally through a differential capacitive barrier.

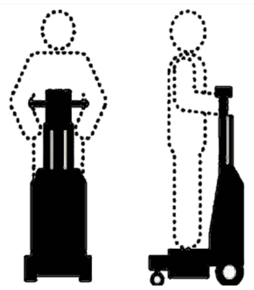


Fig. 1.- Mobility assistance robot of Ahmed et al.

<u>Preamplifier</u>

The small magnitudes of biosignals require an element that can capture and process them, so it must not only be sensitive enough to detect and amplify small signals, but also to discriminate noise or artifacts in order to visualize only EMG activity. The AD620 amplifier helps us to increase the bioelectrical signals of the human body, since they are signals with a magnitude of the order of a maximum of 5 mV, when introduced to another system, they can be dissipated or they can be eliminated when using a system with an incompatible sensitivity. According to the characteristics of the AD620 amplifier, it is suitable for application in the prototype, which is configured to obtain a gain of 100, which allows it to work in an area with a minimum error. Figure 3 shows the configuration of the differential amplifier.

Filtered out

The design of the filter allows to obtain a signal in which the undesirable components are eliminated, for its design the most convenient type to use must be selected. In this case, when working with electromyography, the frequencies used are in the range from DC to 10 KHz. Based on this, two cascaded filters were made, one low-pass and one high-pass to obtain the initial frequency range.

Through experimentation with several subjects, it was determined that the resulting muscular contraction when turning the wheel has its greatest component between 10 and 100 Hz, therefore the filters were adjusted to these components, resulting in the frequency response shown in Figure 5.

Amplification

Once the signal is filtered, it is necessary to make a new adjustment to it to obtain the necessary amplitude to handle it in our output device or to digitize it, for this a basic non-inverting configuration of operational amplifiers is used. This stage is realized using the TL084 op amp, which is a quad package IC, which means it has four op amps inside it and each op amp can be used independently. In this prototype, an amplification of 10 times is used, giving a total amplification of 1000 times considering the pre-amplification performed.

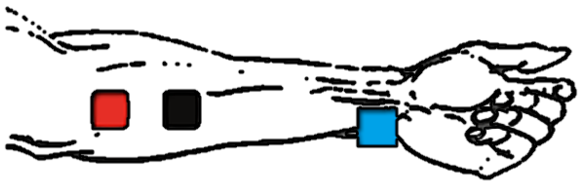
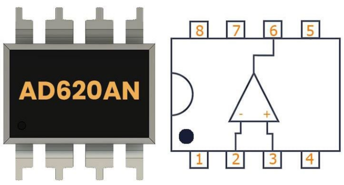


Fig. 2 Suggested electrode placement: Place the pads on the forearm, over the flexor muscle group. In addition to the reference near the closest bone, which in this case is the elbow.



AD620AN	
1. RG	5. REF
2. -IN	6. OUTPUT
3. +IN	7. +VS
4. -VS	8. RG

Fig. 3 AD620 instrumentation amplifier used to pre-amplify the signal coming directly from the electrodes.

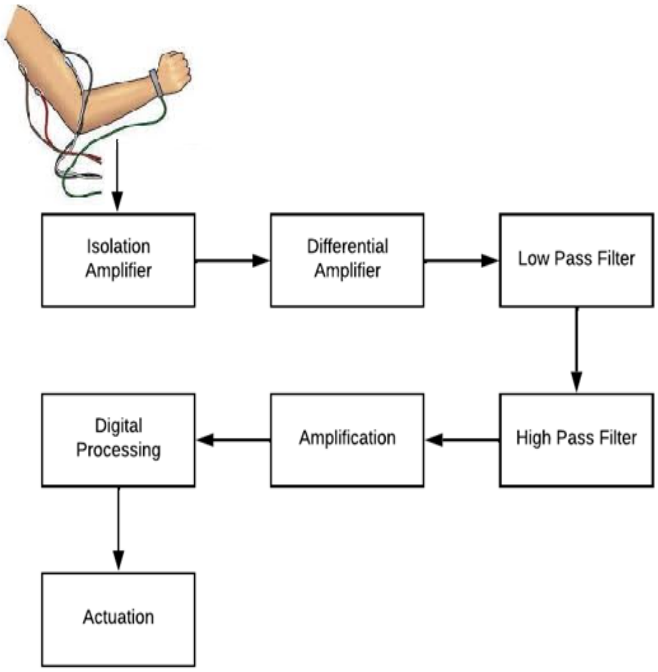


Fig. 4.- Block diagram of the methodology.

Analog to digital conversion (ADC)

By having the signal adequately filtered and amplified, it is required to condition it, in such a way that it can be processed digitally, for this, it is necessary to make adjustments to the output signal, in such a way that it adapts to the card that will acquire the signal for process it, that is, adjusting the offset of the signal so that the negative voltage is eliminated and scaling to the maximum voltage of the card. In this work an ATmega328 microcontroller is used on the Arduino development board which works in a range from 0 to 5v.

To achieve this function, the key is to adjust a reference signal to the offset of the output signal, since in this way it is possible to convert the minimum value of the signal to 0v and the maximum to a value close to 5v. There are multiple circuits that allow this task to be carried out, but in this project a non-inverting configuration of an operational amplifier is used, as shown in Figure 6.

Action Threshold Detection

When obtaining the digitized signal, it must be analyzed whether it is necessary to create a digital filter to eliminate unwanted components that interfere with the detection of the action threshold. In this work, the signal, having an electromyography origin, contains high-frequency signals that are necessary for muscle analysis, however, to use the signal as a means of detecting effort, these components are not necessary, therefore sufficient Exponential Averaging digital filtering is implemented to remove unwanted peaks in the input signal. In this filter, the value of α was determined through experimentation, to find the parameter that would provide a more stable filtering, obtaining a value of 0.05 from the tests. The values of the filtered series F_n from a series of measurements A_n, is determined by equation (1).

$$F_n = F_{n-1} + \alpha(A_{n-1} - F_{n-1}) \quad (1)$$

Once the digital filtering is done, the signal is digitally processed to identify an action threshold that determines a condition to detect the user's effort and does not detect the natural movement of the arm.

Actuation

Once you have the appropriate signal to perform actions, you proceed to the construction of the drive system, this is a circuit that will take the action signal by activating an H Bridge, which in turn controls 2 motors connected to the wheels of the chair, which will serve as support for the user to reduce their effort, the connection diagram is shown in Figure 7. The circuit is powered by 9 V batteries, to make the system portable.

4. Results

The result of the stages used for the acquisition of the biosignal, the circuit of Figure 8 was obtained, in which the components and implemented configurations are presented, both for the filters and for the pre-amplification stage.

The first performance tests carried out on the electromyography detector circuit were to verify the signal when the arm moves without applied force, that is, a natural movement of the arm. For this, a user was connected and tests were carried out with the hand at rest, opening and closing the hand without applying additional force to the movement, in addition, movements of the entire arm were made in different positions, such as: up, down and sideways in the same manner without applying additional than natural force to the movement. All these tests resulted in an almost zero negligible signal, i.e. 0 v at the output, as shown in Figure 9.

The second test with the electromyography circuit is to obtain the desired signal, which is the one that causes the manual movement of a wheelchair by applying force to turn the wheels. This test consists of closing the hand taking the steering wheel of the chair and applying force to generate the movement, then opening to release and repeat the action, to achieve displacement.

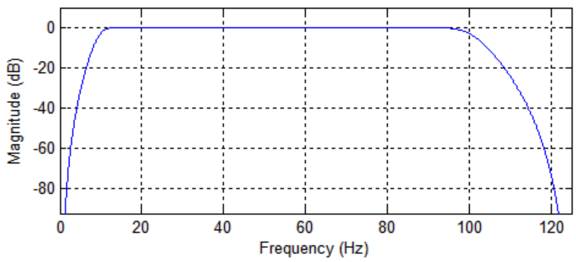


Fig. 5 The figure shows the response of the two filters connected in cascade

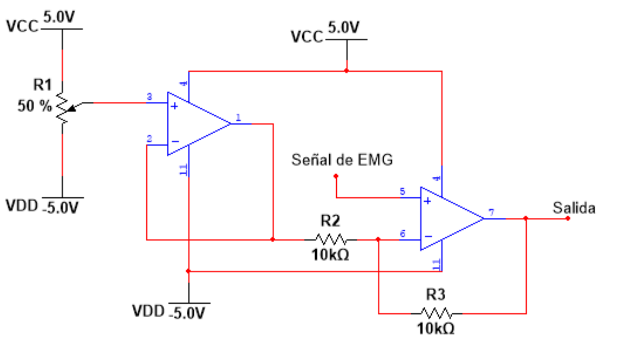


Fig. 6 Electronic circuit for offset adjustment.

Figure 10 shows the real-time test where the signal obtained by the natural movement when moving in a wheelchair is the graph in blue, which shows only the signal obtained without the use of analog filters and in yellow. the signal obtained after all the filtering, in this test it can be seen that the maximum amplitude reached by the filtered signal is 1.89 v at a movement frequency of 0.5 s per stroke cycle. In a third test, the hand was opened and closed repeatedly, applying different forces, this gives us a signal similar to that obtained by the movement of the wheelchair, however there are differences to consider such as the duration of the signal, the times between impulses and the behavior of the component when exerting force. Figure 11 shows the signal obtained from the test where the amplitude varies from 1 to 2 V. Finally, a test was performed with the hand open and making force, but without closing the hand, in order to obtain all the possibilities. of events, with this test a small signal of less than 0.5 V amplitude was obtained (Fig.12).

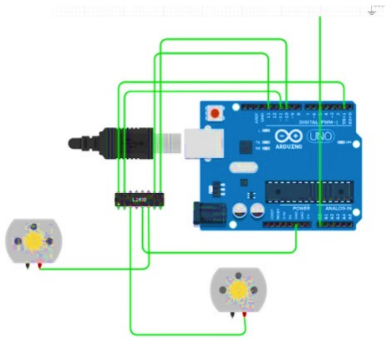
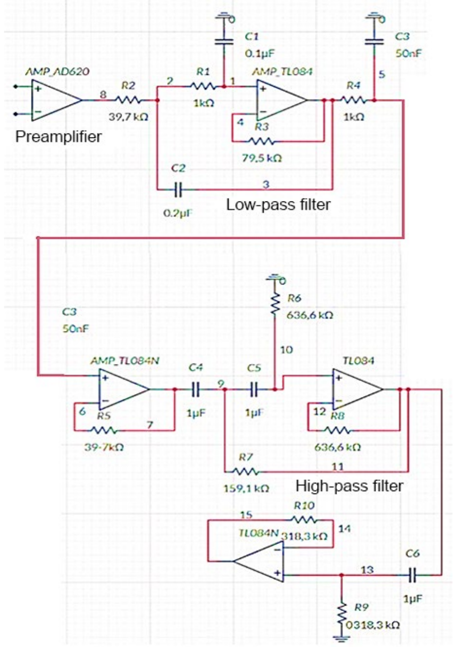


Fig. 7 Electronic circuit for offset adjustment.



Fig, 8 Amplifying and filtering circuit design.

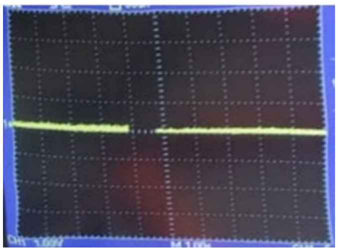


Fig. 9 Completely Resting Hand Signal

The assembly of the physical structure consists of the wheelchair prototype, with the motors that transmit the rotation to the wheels and the circuit that controls the system. The physical assembly is show in the Figure 13. In Fig. 14 we have the fully assembled prototype of the wheelchair working with the electrodes.

Based on the results of tests of moving the wheelchair and repeated clenched hand straining, amplitude discrimination does not eliminate false activation when straining to grasp a heavy object.

For this, the digitization of the signal and its treatment with the exponential average filter is used. Figure 15 shows the signal in blue color of the muscle contraction when force is exerted to move the chair obtained from the analog circuit, in red color the signal is shown with the exponential average filter, in this it can be seen that they eliminate the disturbances or noises of the signal that could affect the control of the chair.

Fig. 10 Signal obtained in a continuous movement of the chair, unfiltered signal in blue color and filtered signal in yellow color.

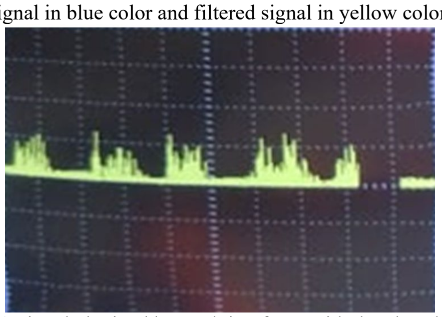


Fig. 11 Signal obtained by applying force with the closed hand.

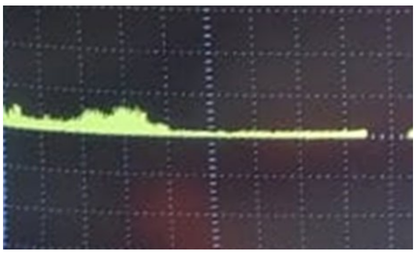


Fig. 12 Signal when open hand and applying force.

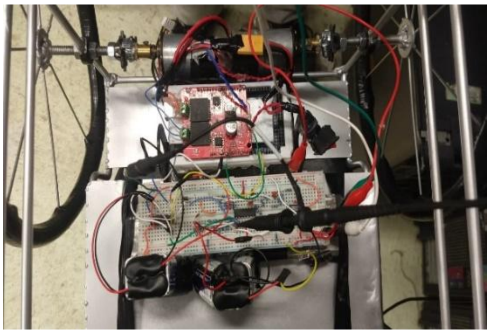


Fig 13 Circuit in the prototype

Figure 16 shows the signal obtained by forcing to grab a heavy object, in the same way, the signal of the analog circuit is blue and the output signal of the exponential average filter is shown in red. Based on Figures 15 and 16, it can be seen that a parameter for the differentiation of the signals is the drop in the signal due to fatigue when grasping an object.

The support system that activates the motors to assist in the effort has the conditions to detect a signal with an amplitude equivalent to the range of 1 to 2 V, detect at least one signal that has a duration of 0.5 s, with rapid polarization and depolarization. Upon meeting these conditions, the system is activated and the movement effort is reduced by the support of the motors.

Figure 17 shows the signal obtained from the electromyograph when the support is activated, the amplitude decreases indicating that there is indeed a decrease in the effort made by the user.

Fig. 14 Scale wheelchair prototype

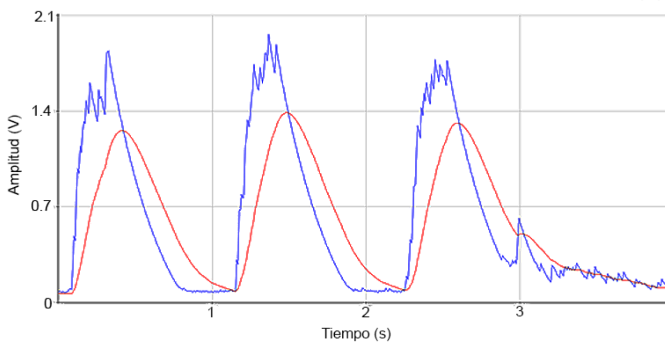


Fig. 15 Signal obtained in the movement of the wheelchair: direct from the analog circuit in blue and digitally filtered in red.

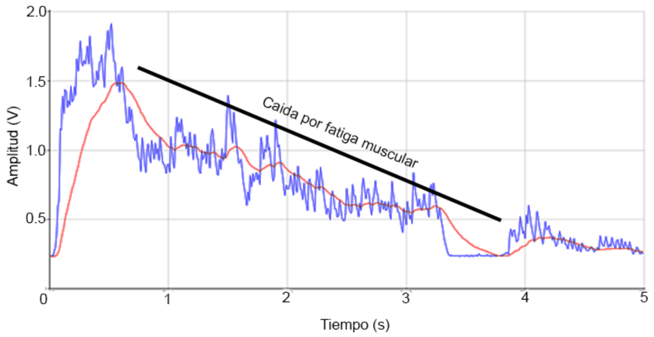


Fig. 16 Signal obtained by exerting force by gripping an object, blue signal without digital filter and red signal with digital filter.

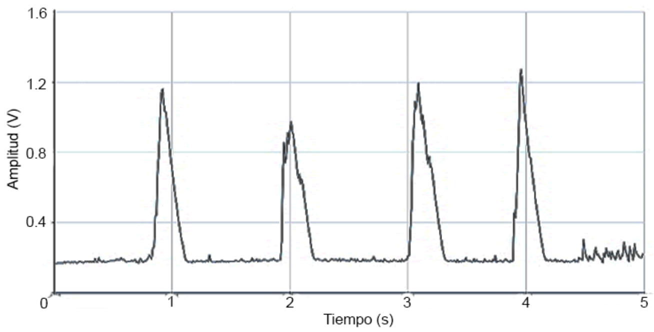


Fig. 17 Electromyograph signal of the effort made with the motors activated

5. Conclusions

It is possible to obtain a prototype of a wheelchair with an assistance system controlled by electromyography. The design of an electromyograph circuit was carried out that allows obtaining the arm muscle signal, filtering it and adapting it to use it as a control signal for the assistance system.

Tests were carried out in multiple scenarios to determine the appropriate signal parameterization to determine when the effort to move a wheelchair is made, to discriminate any signal coming from an effort to grab an object or do an activity.

The implementation of the digital filter makes it possible to identify muscle fatigue caused by a continuous effort to grasp objects, which allows refining the detection of the events of the wheelchair movement and any other signal.

The project is designed to be able to recreate the chair in real size and ready to be implemented in the user in the future, starting with the adaptations to used wheelchairs to make them more accessible to users.

The circuit as such can be improved by introducing an amplifier with better characteristics, as well as the type of electrodes to be used to have a smaller margin of error, rechargeable sources with fixed voltages of 9v and -9v can be used, this for the power supply of the circuit. and the power of our ISO-124p integrated circuit which helps us to avoid any type of noise or distortion due to the movement and vibrations of the motors, which can also be changed for better utility and depending on the user characteristics, referring to specific characteristics such as speed, torque and weight that they can move without problem. The battery that powers the motors can be replaced by a gel battery or an acid battery to activate high-power motors.

This project is designed to provide a more comfortable life for paralyzed users, by receiving help controlled by biosignals, activating motors that make the user's transfer more comfortable.

The reason why this prototype was made and since it is only an aid and not completely electric like many other chairs that already exist on the market, is because at no time is it desired that the user remove the user's physical activation or leave it alone.

Referencias

Ahmed, S. F. et al.,(2018). Mobility assistance robot for disabled persons using electromyography (EMG) sensor. 2018 IEEE International Conference on Innovative Research and Development (ICIRD), 2018, pp. 1-5, doi: 10.1109/ICIRD.2018.8376304.LNCS Homepage, http://www.springer.com/lncs, last accessed 2016/11/21.

Altamirano, M.Á. & Revilla, E.F. (2017). Diseño y construcción del control de silla de ruedas motorizada basada en señales EEG para personas con severa discapacidad en el Hospital Regional de Lambayeque (Trabajo de Grado). Universidad Nacional Pedro Ruiz Gallo, Perú. http://repositorio.unprg.edu.pe/handle/UNPRG/1230

Durán Acevedo, C. M., & Jaimes Mogollón, A. L. (2013). Optimización y clasificación de señales EMG a través de métodos de reconocimiento de patrones. Iteckne, 10(1), 67-76. Retrieved May 21, 2021, from http://www.scielo.org.co/scielo.php?script=sci_arttext&pid =S1692-17982013000100009&lng=en&tlng=es.

Fernández Pascual, Á. (2011). The spinal cord: the cord of life. The story of a quadriplegic by traffic accident. Index de Enfermería, 20(3), 199-202. https://dx.doi.org/10.4321/S1132-12962011000200013

Gago Fernández, I., & Seco Calvo, J. (2010). Independencia funcional para el manejo autónomo de la silla de ruedas. A propósito de un caso. Fisioterapia, 32(1), 41–45.doi:10.1016/j.ft.2009.03.003

Instituto para la Integración al Desarrollo de las Personas con Discapacidad de la Ciudad de México (2016). Manual de normas técnicas de accesibilidad. Jefatura de Gobierno de la Ciudad de México

Küçükyıldız, G., Ocak, H., Şayli, O. & Karakaya, S. (2015). Real time control of a wheelchair based on EMG and Kinect for the disabled people, Medical Technologies National Conference (TIPTEKNO), 2015, pp. 1-4, doi: 10.1109/TIPTEKNO.2015.7374606.

Luengo, E. (2011) Silla de ruedas controlada por movimientos oculares [en línea]. Trabajo Final. Pontificia Universidad Católica Argentina. Facultad de Ciencias Fisicomatemáticas e Ingeniería, 2011. Disponible en: https://repositorio.uca.edu.ar/handle/123456789/11223

Paredes Robalino, E. A. (2019). Diseño e implementación de un sistema de control de la linealidad de la trayectoria de una silla de ruedas manejada mediante comandos de voz, para personas cuadripléjicas. 126 hojas. Quito : EPN.