**EMG Signal Controlled Wheelchair**

**Project Report**

## Introduction

This project presents the development of a smart wheelchair for the people suffering from physical disabilities, controlled by EMG [electromyography] signals. The conventional wheelchairs are not very effective as they require great pedalling.

The EMG signal is a biomedical signal that measures electrical currents generated in muscles during its contraction representing neuromuscular activities. The nervous system always controls muscle activity (contraction/relaxation). Hence, the EMG signal is a complicated signal, which is controlled by the nervous system and is dependent on the anatomical and physiological properties of muscles. EMG signal acquires noise while travelling through different tissues. These EMG signals are acquired using EMG sensors attached to the muscles of arms and are read in Arduino Uno board working with an AVR microcontroller.

A smart wheelchair typically consists of either a standard power wheelchair which has a computer and a collection of sensors added to it or a mobile robot base to which a seat has been attached. It has been designed to provide navigation assistance to the user in a number of different ways, such as assuring collision-free travel, aiding the performance of specific tasks (e.g., passing through doors and corridors), and autonomously transporting the user between locations. There are various researches that are undergoing with EMG controlling the battery powered wheelchairs.

## Why EMG Signal?

The joysticks in the wheelchair are the traditional method for its navigation. Another method developed later was using 3D joysticks in addition to the EMG signal for easy and convenient use. But, these methods have a limiting factor since it can be used only by people who still have some sort of control, enough for manipulating it. So, for people who suffer from severe motor impairments, different types of technologies were used to create smart wheelchairs. One such alternative way is employing electromyography signals (EMG) for this purpose.

This specific type works with muscle signals analysis offering resources for controlling different types of systems and interfaces.

### Analysis of EMG Signals

The electrodes present in the EMG sensors are attached to hand muscles for acquiring the EMG signals that have been amplified by the inbuilt amplifier circuit. The resultant signal is passed through a Bessel filter circuit which is further converted into digital samples so as to control the Wheelchair. To rotate the wheel chair there are some special cases taken into consideration. The cases are as follows:

1. Flex to rotate the wheel chair.

2. Relax to stop at a particular point.

3. If you flex for 2 seconds straight, you'll trigger the lock mechanism and the motors will start to rotate left.

4. There is a proper setting of threshold level which decides whether the Wheel chair should be moved left or right.

5. To take the lock off, simply flex for another 2 seconds and the wheel-chair will stop.

The whole process is tested with a few voltmeters. The controller is programmed in accordance with the stress created by the muscle. If the produced stress appears in some range then it will generate the signal accordingly. Thus the commands to the wheelchair will vary with respect to the pulse.

## The physiology of EMG Signals

The EMG signal is generated by the electrical activity of the muscle fibres active during a contraction. Skeletal muscles are made up of a collection of motor units(MUs). A motor unit is the smallest muscle unit that can be activated by volitional effort. The constituent fibres of the motor unit are activated synchronously. Component fibres of a motor unit extend lengthwise along the muscle. The mechanical output of a muscle is the net result of stimulation and contraction of several of its motor units.

When stimulated by a neural signal, each motor unit contracts and causes an electrical signal that is the summation of the action potentials of all its constituent cells. This is known as Single Motor Unit Action Potential. Normally SMUAPs are biphasic or triphasic.

Muscle contraction levels are controlled by two methods, Spatial recruitment and Temporal recruitment. Spatial recruitment is where new motors are activated with increasing effort and temporal recruitment is achieved by increasing the frequency of discharge of each motor unit with increasing effort. The spatio-temporal summation of the MUAPs of all the active motor units gives rise to the EMG of the muscle

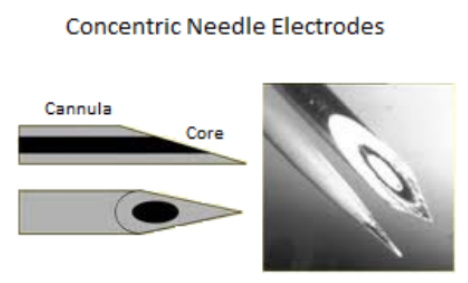
## Signal Acquisition

There are three major kinds of electrodes used for EMG signal acquisition :

1. Needle Electrodes
2. Fine wire electrodes
3. Surface EMG electrodes

#### Needle Electrodes

Needle electrodes are widely used in clinical procedures in neuromuscular evaluations. The tip of the needle electrode is bare and used as a detection surface. It contains an insulated wire in the cannula. The signal quality from the needle electrodes is comparatively improved from other available types. Needle electrodes have two main advantages. One is that its relatively small pickup area enables the electrode to detect individual MUAPs during relatively low force contractions. The other is that the electrodes may be conveniently repositioned within the muscle (after insertion) so that new tissue territories may be explored. However these electrodes require a medical supervisor and are a bit painful. The needle electrode is as follows:

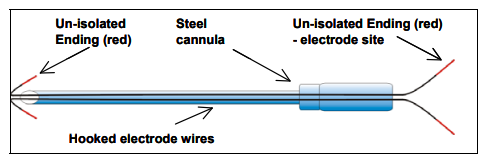


#### Fine Wire Electrodes

In the cases when the muscles are deeply located in a body segment or covered by other surface muscles, the fine wire electrodes are necessary for accuracy.The EMG recordings from thin and deep muscles are difficult to obtain due to crosstalk from adjacent muscle layers. Hence surface electrodes are not preferred in such scenarios. Fine wire electrodes are made from any small diameter, highly non-oxidizing, stiff wire with insulation. Alloys of platinum, silver, nickel, and chromium are generally used. Wire electrodes are extremely fine hence the name fine wire electrodes.

Although fine wire electrodes can be manipulated while monitoring EMG activity and are suitable for clinical investigations, accurate placement of fine wire electrodes is more difficult than the surface EMG electrodes. They must hook into the desired muscle layer and cannot be repositioned once inserted. Once inserted, fine wire electrodes are superior for prolonged and non-clinical investigations of muscle function because they are hooked in the muscle fibres and therefore move with the fibres ensuring that the recording area is the same.

A typical fine wire electrode is as follows:



#### Surface EMG Electrodes

Surface EMG electrodes provide a non-invasive technique for measurement and detection of EMG signals. The theory behind these electrodes is that they form a chemical equilibrium between the detecting surface and the skin of the body through electrolytic conduction, so that current can flow into the electrode. These electrodes are simple and very easy to implement.

Application of needle and fine wire electrodes require strict medical supervision and certification. Surface EMG electrodes require no such formalities. Surface EMG electrodes have found their use in motor behaviour studies, neuromuscular recordings, sports medical evaluations and for subjects who object to needle insertions such as children.

Apart from all this, surface EMG is being increasingly used to detect muscle activity in order to control device extensions to achieve prosthesis for the physically disabled and amputated population.

Surface EMG has some limitations as well. Since these electrodes are applied on the skin.

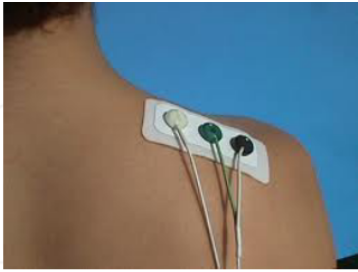
Hence, they are generally used for superficial muscles only. Crosstalk from other muscles is a major problem. Their position must be kept stable with the skin; otherwise, the signal is distorted.

There are two types of surface EMG electrodes:

#### Gelled EMG electrodes

Gelled EMG electrodes contain a gelled electrolytic substance as an interface between skin and electrodes. Oxidation and reduction reactions take place at the metal electrode junction. Silver – silver chloride (Ag-AgCl) is the most common composite for the metallic part of gelled electrodes. The AgCl layer allows current from the muscle to pass more freely across the junction between the electrolyte and the electrode. This introduces less electrical noise into the measurement, as compared with equivalent metallic electrodes (e.g. Ag). Due to this fact, Ag-AgCl electrodes are used in over 80% of surface EMG applications.

Disposable gelled EMG electrodes are most common; however, reusable gelled electrodes are also available. Special skin preparations and precautions such as (hair removal, proper gel concentration, prevention of sweat accumulation etc.) are required for gelled electrodes in order to acquire the best possible signal. Gelled EMG electrodes are shown in the figure below:



#### Dry EMG Electrodes

Dry EMG electrodes do not require a gel interface between skin and the detecting surface. Bar electrodes and array electrodes are examples of dry electrodes. These electrodes may contain more than one detecting surface. In many examples, an in-house pre-amplification circuitry may also be employed in these electrodes. A reusable bar electrode is shown in the figure below. Dry electrodes are usually heavier (>20g) as compared to gelled electrodes (<1g). This increased inertial mass can cause problems for electrode fixation; therefore, a material for stability of the electrode with the skin is required.



During the hand movements there will be some contraction created by muscle by which some pulse signals are generated. The pulse signals differ with the contraction and relaxation of muscles. The function of the sensor module is to record these pulse signals which are obtained as the product of contraction. The output of the EMG sensor module will be an analog pulse signal which is further given to the analog pins of Arduino Uno that has an internal ADC to convert these signals into digital signals. These digital signals are then processed by the microcontroller on Arduino for further processing. These Sensors are designed to be used directly with a microcontroller.

**Signal Filtering**

The surface electromyographic (sEMG) signal contains the signal that originates in the muscle and various noise components which are endemic and unavoidable. These noise components contaminate the sEMG signal and may lead to an erroneous interpretation of the signal. This is especially the case when the signal is obtained during dynamic contractions and when it is meant to provide information concerning the physiology and anatomy of muscles.

The frequency spectrum of the sEMG signal collected with commonly used sensors ranges from 0 to 400 Hz, depending on the electrode spacing, the amount of fatty tissue between the skin and the muscle tissue, the shapes of the action potentials, and muscle type.

At the high-frequency end of the sEMG signal spectrum, the low-pass filter corner frequency (the boundary of the filter’s frequency response where signal energy is attenuated by 3 dB), should be set where the amplitude of the noise components surpasses that of the sEMG signal. Consequently, it is preferable for the high end of the sEMG frequency spectrum to have a low-pass corner frequency in the range of 400–450 Hz.

At the low-frequency end of the spectrum, the choice of the location of the high-pass filter corner frequency is more involved because several noise sources contribute signals whose low- frequency spectra overlap with that of the sEMG signal.

**Sodium-Potassium pump**

Sometimes, there might be a case that a large concentration of a substance is required in the fluid inside the cell even though only a small ion concentration is present outside the cell which is the norm, in case of potassium ions.Conversely, low concentration in the fluid inside the cell and high in the fluid outside it is the case of sodium ions.This process cannot happen by means of diffusion and it instead characterised by excess movement of potassium ions inside the cell and sodium ions outside the cell which is called active transport because of travel of ions against electric or pressure gradient.

There are two types of active transport-primary active transport,where energy is derived directly from the breakdown of ATP,and secondary active transport,the energy is derived from the energy stored due to the concentration difference on either side of the cell membrane caused due to primary active transport.Both depend on carrier proteins for the transport but in case of active transport carrier proteins work differently than in diffusion because it has to impart energy to move electrons to a higher gradient.One of the examples of primary active transport is the aforementioned sodium-potassium pump.

Sodium potassium pump is a transport process responsible for pumping in potassium ions from outside to the inside of the cell membrane while simultaneously pumping sodium ions from the inside to the outside so as to maintain the difference in sodium potassium concentration across the cell membrane and establishing a negative electrical cell voltage.

It contains carrier protein which includes a complex of 2 separate proteins called as alpha subunit, which has a higher molecular weight, and beta subunit, with much lesser molecular weight.Although the function of the smaller subunit is unknown, the larger subunit has three important features for pump functioning-3 receptor sites for binding sodium atoms,2 receptor sites for binding potassium atoms and binding sites that have ATPase activity.

One molecule of ATP is cleaved into ADP and high - energy phosphate bond of energy which results in extrusion of 3 sodium ions to the outside and 2 potassium ions to the inside of the cell membrane. Ofcourse, like with other enzymes, this pump can also work in reverse if the energy stored in the gradient is greater than that of ATP hydrolysis. In such a case ATP is synthesised from ADP and phosphate.

Sodium potassium pump is used for controlling cell volume.The process pumps two potassium ions inside the cell and three sodium ions outside it. As the membrane is far less permeable to sodium ions than potassium ions, sodium ions tend to stay outside. This process also initiates osmosis of water outside the cell and hence represses the phenomenon if any cell has a tendency to swell.

In Sodium - potassium pump because three ions exit the cell while two ions enter it, this creates positivity outside the cell but results in negativity on the inside.Thus, sodium potassium pump creates an electrical potential across the cell member and is widely known to be electrogenic.This electrical potential is the main requirement in nerve and muscle fibre used for nerve and muscle signal transmission.

The resting membrane potential of large nerve fibres when not transmitting nerve signals is about -90mV. Which means that the potential inside the fibre is 90mV more negative than on the outside.Sodium -potassium pump is observed to have provided more contribution to this resting potential.The pumping of three Na ions to the outside and two K ions to the inside results in a negative potential of -4mV,which is more than what occurs from diffusion alone.

The transmission of each action potential across the nerve fibre influences the difference in concentration slightly due to polarisation and depolarisation.About 100,000 to 50 million impulse can be transmitted through the nerve fibre of the human body before concentration becomes very high and this action potential threatens to stop.Hence, it is necessary to restore the Sodium and potassium membrane concentration membrane which is achieved by means of the sodium - potassium pump.