Applications Of Electromyography

Ankit
dept. of Mechatronics Engineering
Chandigarh University
Punjab, India
ankitchawla300@gmail.com

Vansh
dept. of Mechatronics Engineering
Chandigarh University
Punjab, India
vanshaggarwal2305@gmail.com

Vineet
dept. of Mechatronics Engineering
Chandigarh University
Punjab, India
vinisharda2003@gmail.com

Malavika S
dept. of Mechatronics Engineering
Chandigarh University
Punjab, India
sureshmalavika724@gmail.com

Yashik
dept. of Mechatronics Engineering
Chandigarh University
Punjab, India
yashiksharma5@gmail.com

***Abstract*— This paper describes our research about electromyography. The focus points of our paper are: signal detection and signal processing of electromyography - its importance, applications, electrical noise, factors affecting EMG signal, types of electrodes - its advantages and disadvantages, sEMG - advantages and disadvantages. Through this research paper we aim to put forward the significance and scope of EMG to the upcoming knowledge seekers.**

***Keywords*—electromyography, signal detection, signal processing, electrical noise, sEMG, invasive EMG**

I. INTRODUCTION

Electromyography, like many other technologies, was discovered long before inexpensive and robust hardware was developed to exploit the vast amount of information available from myoelectric signals. Until recently, existing technology couldn't support economical generation of repeatable strong signals for even extremely subtle analysis laboratories, not to mention the widespread handiness of affordable, robust hardware needed to propagate diagnostic techniques through the research communities. Real-time analysis is now possible thanks to new high-speed computation tools. With the advent of inexpensive hardware, high-speed wireless communication technology, and low-cost high-speed computers / signal processing equipment, EMG has become available for a whole new series of experiments. These advances make EMG a viable option in many situations, surface EMG (sEMG) is a convenient and relatively non-invasive technology suitable for determining muscle activation, especially here in portable devices. We see the emergence of an important period in the development of technologies that provide non-invasive methods. Of course, given the benefits of broader availability, this proliferation as relevant practitioners move from EMG specialists to specialists who use EMG part-time or to technicians in other disciplines who only occasionally experiment. You need to consider the risks associated with. [1]

II. ELECTROMYOGRAPHY

Electromyography (EMG) is a diagnostic procedure to assess the health of muscles and the nerve cells that control them (motor neurons). EMG results can reveal nerve dysfunction, muscle dysfunction or problems with nerve-to-muscle signal transmission. Motor neurons transmit electrical signals that cause muscles to contract. An EMG uses tiny devices called electrodes to translate these signals into graphs, sounds or numerical values that are then interpreted by a specialist. During a needle EMG, a needle electrode inserted directly into a muscle records the electrical activity in that muscle. A nerve conduction study, another part of an EMG, uses electrode stickers applied to the skin (surface electrodes) to measure the speed and strength of signals traveling between two or more points.[2]

III. IMPORTANCE OF ELECTROMYOGRAPHY

EMG itself is emerging as a wider topic which has great applications ranging from zero to infinity and there are many more to be discovered yet. The main importance lies in the medical field where the ancient practice to remain amputated a whole life has changed to bionic arms and prosthetics which brought a new significance to thousands of lives out there. EMG helps in the diagnosis and prevention, to a great extent, of muscle disorders, neuromuscular diseases, motor neuron malfunctions, nerve dysfunction, etc.[3]
EMG is of importance in many research laboratories for conducting advanced studies including biomechanics, motor control, neuromuscular physiology, movement disorders, postural control, physical therapy. etc.[4]

IV. EMG SETUP DESCRIPTION

For acquiring the EMG signal, we basically require four things which includes

1. *Electrodes* : these carry signals from muscles to the EMG sensor.
2. *EMG sensor* : It is a circuit consisting of an onboard amplifier and filters to process the raw EMG signal (0-10 mV) taken from muscles through electrodes and converts into a signal which any microcontroller like arduino can read. In our project we are using an EMG sensor from advancer technologies.
3. *Microcontroller* : To receive data from an EMG sensor and display it in a laptop or oscilloscope.
4. *Laptop or oscilloscope :* To display data received from the EMG sensor.[5]

V. SIGNAL DETECTION

In the analysis of motor systems, the important issue is the precise detection of discrete events in the surface EMG. Several methods are there for detecting the on and off timing of the muscle.The most common method is visual inspection by trained observers, where the motor-related events from EMG signals are resolved. Another method is the "single-threshold method," which compares the EMG signal with a fixed threshold. This is the most intuitive and common computer-based method of time-locating the onset of muscle contraction activity. In this technique, a comparison is made between the rectified raw signals and amplitude threshold, whose value depends on the mean power of the background noise. This method rectifies any problems occurred during visual inspection which gives a precise result. However, this kind of approach is generally unsatisfactory, since choice of threshold is the strong focus in measured results. These kinds of methods do not allow the user to set the detection and false alarm probabilities independently.

To overcome the problems occurring in the single-threshold method, in 1998 Bornato et al introduced the 'double-threshold detection'. This method yields higher detection probability than the single-threshold method. This also allows the user to link between detection and false alarm probabilities with a higher degree of freedom than the latter.

Later this method was found complex and computationally expensive by Lanyi and Adler in 2004. They proposed a new algorithm that is based on the double-threshold method that is more sensitive, stable and with decreased computation cost. Besides the accuracy, the speed of this algorithm is an important consideration. Signal-whitening is not needed in this method compared to the latter. This method provides a fast and more reliable muscle on-off detection.

Among the three methods discussed here, the third one is the best practice and provides a precise detection.[6]

VI. EMG SIGNAL PROCESSING

Raw EMG provides valuable information in a particularly useless way. This information is only useful if it can be quantified. The processed signals are of great importance in the field of clinical diagnosis and biomedics. Various signal processing techniques are applied to raw EMG to obtain accurate and real EMG signals. The various methods used in signal processing are discussed below:[7]

Wavelet analysis

In signal analysis, the time-frequency plane is one of the most fundamental concepts. The Wigner-ville distribution (WVD) is one of the time-frequency representation methods that is used for EMG signal analysis. In 1992, Ricamato *et al.* showed that it is possible to present the frequency ranges of the motor unit by WVD. An excellent localization property of WVD is that it is highly concentrated in the instantaneous frequency and time of the signal. But this method is not well suited for analyzing a multi-component signal like EMG because it is having a cross-term effect and is very noisy. This wavelet transform method can be divided into discrete and continuous wavelet transforms.

Continuous Wavelet Transform (CWT) method is more consistent and less time-consuming than Discrete Wavelet Transform (DWT) due to the absence of down sampling. For the analysis of non-stationary signals like EMG signals, DWT is often successful but it yields a high-dimensional feature vector.

Autoregressive Model

Autoregressive time series model has been used to study EMG signals. In this model, a surface electrode will grab the EMG activity from all active muscles in its range, while the intramuscular EMG is highly sensitive, with only minimal crosstalk with adjacent muscles. Thus to combine convenience and accuracy, there is a great requirement to develop a technique for estimating intramuscular WMG and their spectral properties from surface measurement. Thus researchers have represented sEMG signal as an AR model with the delayed intramuscular EMG as input.

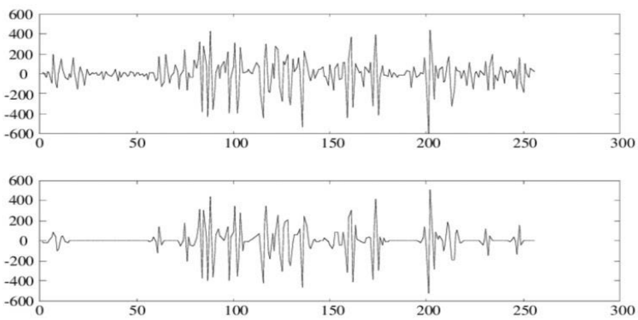

Fig.6 shows the difference between raw and processed signals respectively.

VII. ELECTRICAL NOISE

Range of the raw EMG signal is 0-10 mV before amplification. EMG signals pick up noise as they pass through various tissues**.** EMG signals acquire noise while traveling through different tissues. It is important to understand the characteristics of electrical noise. Electrical noise, which will affect EMG signals, can be categorized into the different types:[8]

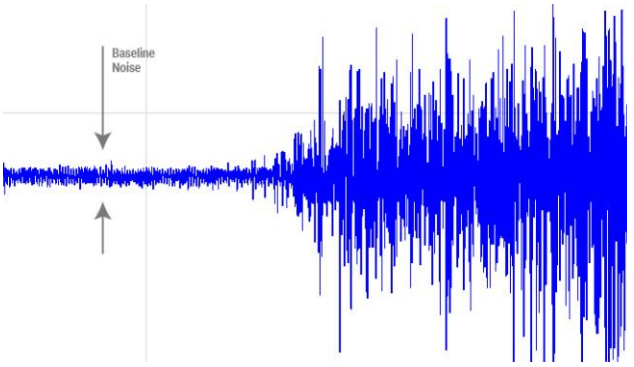

Fig. 7 shows the noise in the EMG Signal

VIII. FACTORS AFFECTING EMG SIGNAL

1. *Inherent noise in electronics gadgets* : All electronic devices generate noise. This noise can't be removed; the use of excellent electronic components can best reduce it.
2. *Ambient noise:* Electromagnetic radiation is the source of this type of noise. The surfaces of our bodies are continuously inundated with electromagnetic radiation and it is definitely not possible to keep away from exposure to it at the floor
3. of earth. The ambient noise may additionally have amplitude which is one to 3 orders of value extra than the EMG signal.
4. *Motion artifact:* whilst movement artifact is delivered to the device, the statistics is skewed. movement artifacts cause irregularities within the statistics. There are 2 principal sources for movement artifacts: 1) electrode interface and 2) electrode cable. movement artifacts may be decreased through the right layout of the electronics circuitry and set-up.
5. *Inherent instability of signal*: The amplitude of EMG is random in nature. EMG signal is stricken by the firing rate of the motor gadgets, which, in maximum situations, fire within the frequency area of zero to twenty Hz. This form of noise is taken into consideration as undesirable and the elimination of the noise is crucial.[9]

IX. TYPES OF ELECTRODES USED IN EMG

Basically EMG is classified into 2 main types according to the type of electrodes used.
A. *Invasive* : In this type, a needle or thin wire is used as an electrode and is inserted directly into the skin.
B. *Non invasive or sEMG* : In this type, electrodes are not inserted directly into the skin, rather, electrodes are attached on the surface of the skin.

Further sEMG is classified into two parts.

a. *gel electrodes :* These electrodes are disposable electrodes as it is meant for one time use only. It has a layer of adhesive which sticks to the body of the subject and uses a layer of gel to conduct even minute signals from the muscle to the sensor.
b. *dry electrodes :* basically these are reusable electrodes made of metal. It does not require any kind of conductive gel or solution for conducting signals from muscle to the sensor. However, it does not work on completely dry skin because it requires a small amount of moisture to conduct signals.[10]

X. ADVANTAGES AND DISADVANTAGES OF sEMG

The main advantage of sEMG is that it is easy to use and not painful as unlike the invasive technique, the electrodes are not inserted into the skin, rather the electrodes are placed on the surface of the skin. It provides more region for recording the EMG signals and is safer than invasive types of EMG. Apart from these advantages, it has some disadvantages too. Through this we can only measure EMG signals of the muscle which are present on the surface and also it has a low signal to noise ratio and due to that the extraction of useful signals becomes difficult. [11]

XI. ADVANTAGES AND DISADVANTAGES OF INVASIVE ELECTRODES

The main advantage of this type of electrode is that it has a very high signal to noise ratio, so we can easily extract the useful signal from the data. Since the electrodes are inserted deep inside the muscle, we can explore a lot of data from the muscles which are hidden deep below the surface of the skin. Also it is capable of detecting MUAP. Apart from these advantages, it has some disadvantages too. One of the major disadvantages is that it is difficult to use and the needle electrodes have to be inserted precisely and also inserting the needle inside the surface of the skin which is a very painful procedure. It follows a pretty risky procedure and also obstructs the motion of the part of the body in which the needle electrodes are attached.[12]

XII. APPLICATIONS OF EMG

Medical field : EMG is used as a tool for assessing Neuromuscular and motor control disorders. Also in kinesiology, EMG tells a lot about the degree & sequence of contraction and expansion of different muscles participating in a movement. EMG may be used to examine muscle disorder in athletes, discover irrelevant muscle activation styles and help in setting up and assessing remedy results in situations like incontinence and low back pain. Low back pain in athletes is a situation immune to treatment, and knowledge of this syndrome has been inclusive of kinesiology and biomechanics. feasible best through the usage of EMG. The observation of postural and neuromuscular control responses has established that these responses vary in low back pain and healthy subjects. Surface EMG has been used to assess the useful status of skeletal muscle groups and help in neuromuscular training. EMG plays a prime role within the analysis of muscular dystrophy, which is a set of genetic diseases that cause progressive weakness and lack of muscular tissues. Some peculiar genes intrude with the protein manufacturing required for wholesome muscle groups. This disease has no treatment till date and the lifespan of someone who is laid low with this, is frequently shortened. The health practitioner's opinion is that only treatment can help this condition. EMG helps in obtaining alerts and present situations of the muscle groups which assist the medical doctors to act consequently. The sensitivity and accuracy of this technique facilitates the detection of myogenic modifications even at the subclinical, oligosymptomatic degree of impairment. The EMG abnormality detected was an elevated percent of polyphasic potentials and reduced in amplitude, location, MUAP length, interference sample amplitude and amplitude length. [13]

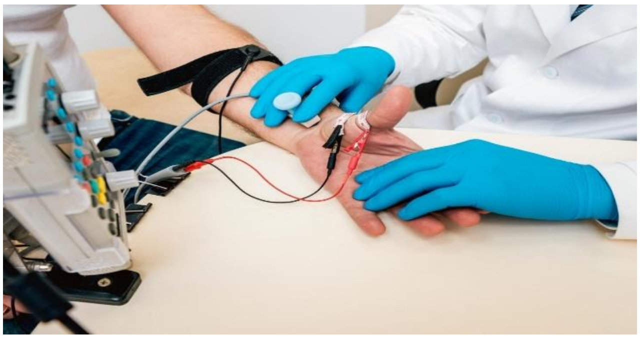

Fig.12.1 show a doctor performing EMG test on the patient's hand.

Rehabilitation technology : Surface electromyography or sEMG is a widely used technology in the field of rehabilitation technology. It acts as a signal for operating various assistive devices such as bionic arm, artificial limbs and legs to help people with disability in regaining their lost mobility and do their daily routine jobs independently. It gives quantifiable statistics at the myoelectric output of a muscle.The immediate quantification of muscle reaction can function as an essential component to find out the impairment in addition to healing at some point of the rehabilitation. upper limb prosthetics were available in some shape for millennia. In recent decades, those prosthetics have evolved from pretty rudimentary inflexible gadgets to single degree of freedom (DOF) gadgets, managed by way of motion of the shoulder inside of a mechanical harness. More currently, modern-day upper limb prosthetics have used EMG to govern a lot of superior gadgets, incorporating extra complicated movement into decreased order gadgets and more than one DOF device closely equivalent to real palms and fingers.[14]

Fig. 12.2 shows a bionic arm developed by Open Bionics in collaboration with DEUS Ex

Human exoskeletons : have undergone rapid development recently, and are enjoying a surge in popularity. For rehabilitation of patients with reduced ability due to illness or advanced age, it can be the most suitable technology. To amplify the efforts of able bodied workers, providing additional strength, reach, or range of motion, this method may also be a

valuable method and additional features can even be employed in which the wearer controls an additional device. It can be suitable for paraplegic patients with no muscle signal to measure, or patients with other disorders causing spastic muscle behaviour

.

Fig 12.3 shows a person using EMG operated exoskeleton

Gesture based remote control : The increased integration between technology and humans has led to very intuitive control of various devices. For eg. Myoelectric arm-band can be integrated to the person's arm and can be used to control various types of assistive devices like bionic arm. Use of Myo Armband is not just limited to application in the prosthetic field. Interestingly, it can be used in various other fields. We can use it to play games or even we can control our presentation screen wirelessly just by making certain gestures.

Fig. 12.4 show the Myo Armband for gesture recognition.

XIII. HARDWARE IMPLEMENTATION

In our setup we have used an EMG sensor by Advancer Technologies which uses surface electrodes to carry signals from targeted muscle to the sensor. It has 5 pins which includes +Vs, GNd of Voltage source, -Vs, sig(signal) and common ground pin for sensor and Arduino Uno. The Signal pin can be connected to any analog pin of the Arduino Uno board. Also this board has an onboard filter circuit to give the processed data and a potentiometer for adjusting the gain.

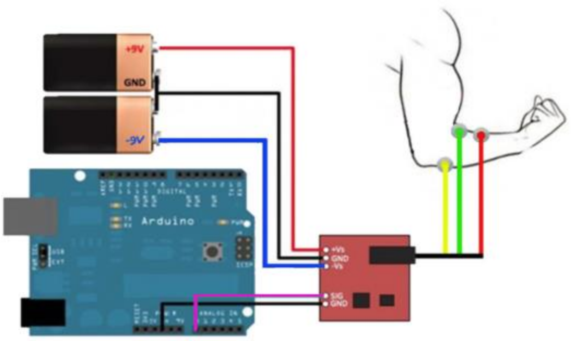

Fig. 13.1 displays the schematics of all the connections to the EMG sensor from Arduino UNO and the electrodes.

As displayed in the figure above, 3 electrodes are used in this process. Two of them are placed along the targeted muscle (red and green) and the 3rd electrode (yellow) is used for ground or reference which is placed below the elbow. Whenever we flex the muscle, the electric potential is generated in the muscle and can be detected by the EMG sensor with the help of these electrodes. The

EMG sensor the sends the processed signal to the Arduino UNO which in turn operates the required device like the servo motor which can be used in bionic arm or can be used to to display the EMG signal in RGB leds. We have programmed a code in MATLAB which changes the colour of a common anode RGB led according to the amount of force we use to flex the muscle.

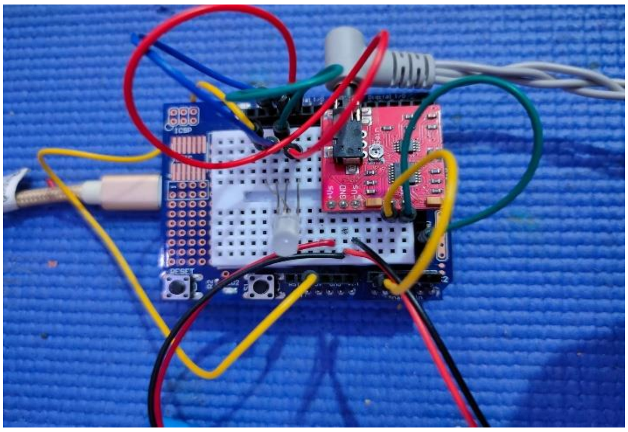

Fig. 13.2 displays the connection of muscle sensor V3 kit connect with Arduino UNO on proto-board shield

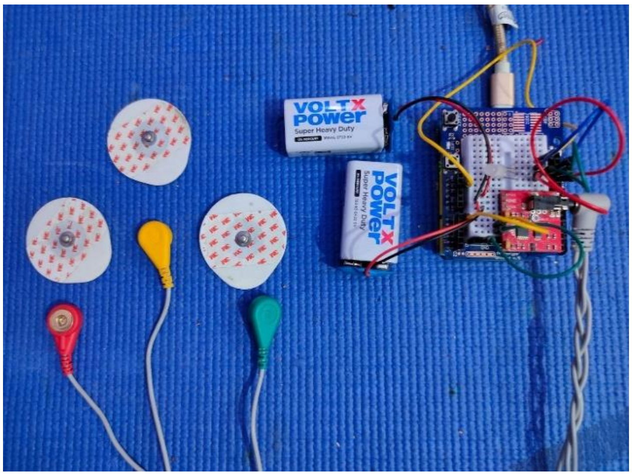

Fig. 13.3 displays the picture of complete setup

XIV CONCLUSION

EMG possesses great value in this technically advanced world as it is spread over every field in one or the other means. The connection between muscles and nerves is something that has fascinated many scientists which resulted in this bionic era and opened a wide span of research area. In this paper, we jotted down the research we conducted on this vast topic. This includes a brief about EMG and its importance, EMG setup, signal detection, signal processing, types of electrodes and their advantages and disadvantages, applications of EMG, etc. From the research, we learned deeply about EMG and its scope in the near future. The significance of this topic has indeed brought a new perspective towards technological advancement and human well-being.

References

[1]https://en.tpwikipedia.org/wiki/Electromyography

[2]https://www.mayoclinic.org/tests-procedures/emg/about/pac-20393913

[3]https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3789163/

[4]https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1455479/

[5]https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/electromyography-emg

[6]https://webstor.srmist.edu.in/web_assets/srm_mainsite/files/files/ELECTROMYOGRAPHY.pdf

[7] https://www.jetir.org/papers/JETIR1507026.pdf

[8] https://www.intechopen.com/chapters/40113

[9] https://www.hindawi.com/journals/bmri/2014/169459/

[10] https://en.wikipedia.org/wiki/Electromyography

[11] https://www.healthline.com/health/electromyography

[12]https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1528-1157.1997.tb04541.x

[13] https://www.intechopen.com/chapters/43488

[14]https://www.sciencedirect.com/topics/computer-science/assistive-devices