

Design and Implementation of GUI Package for the Muscle Diseases Recognition Based on EMG Signals

Yousif I. Al Mashhadany, Eman Huassan, Aseel Najeeb

Abstract- An artificial neural network (ANN) provides a comprehensive and specialized service for the diagnosis and care of muscle diseases. Medical consultations are offered at the neuromuscular clinics, which are staffed by neurologists with special expertise in muscle diseases. This work presents the design and implementation of muscle diseases detection based on real electromyography (EMG) signals. This paper consists of three main parts. The first part presents the measurement of the signals of real human arm muscles (EMG signal). The data are then rearranged and recorded using EMGLab software. Surface electrodes are used to measure the real EMG signals. The suitable features of signal are extracted for classification. The second part applies signal requirements, such as filtering amplification and normalization, using MATLAB or any software. Muscle diseases were classified using an ANN package based on the features of EMG signals, amplitude of signals, and period of signals to identify the diseases. The third part explains the design of the graphical user interface based on MATLAB to implement the classification on real EMG signals. Satisfactory results are obtained from numerous executions with different cases of human arm muscles, thus ensuring the feasibility of this design for practical implement in hospitals or private clinics.

Index Term- Electromyography (EMG) signals; Graphical User Interface (GUI); EMGLab software.

I. INTRODUCTION

Electromyography activity is recorded from contracted arm muscles upon execution of the instruction from the brain. Electromyography (EMG) is used to recognize the movements developed by individual muscles while crossing the bones of the body. Muscle refers to the tissue of the body that primarily functions as a source of power. Muscles in the body are of three types.

Muscles responsible for moving extremities and external areas of the body are called "skeletal muscles." Heart muscles are called "cardiac muscles." Muscles in the walls of arteries and bowels are called "smooth muscles."

Nerve is a fiber that connects the brain and spinal cord with various parts of the body (—also called receptor organs). Nerves conduct impulses from the brain/spinal cord to these receptor organs as well as from the receptor organs back to the brain/spinal cord [1].

EMG is a technique used to evaluate and record the electrical activity produced by skeletal muscles. EMG is performed using an instrument called an electromyography to produce a record called an electromyogram. Electromyography detects the electrical potential generated by muscle cells when such cells are electrically or neurologically activated.

Manuscript Received on May, 2014.

Asst. Prof. Dr. Yousif Ismail Al Mashhadany, Electrical Engineering Department, Engineering College, University of Anbar, Anbar, Iraq.

Eng. Eman Huassan and Eng. Aseel Najeeb, Electrical Engineering Department, Engineering College, University of Anbar, Anbar, Iraq.

The signals can be analyzed to detect medical abnormalities, activation level, and recruitment order or the biomechanics of human or animal movement [2].

Many common medical conditions, such as diabetes, can cause nerve damage. In such cases, the longest nerves are usually affected first, thus the term peripheral neuropathy. Even when diabetes is controlled with diet or oral and injectable medications, nerve damage often occurs. An EMG/NCS can evaluate the severity and monitor any progression of a peripheral neuropathy.

Myopathy is a disease that is localized to the muscle and muscle-supporting structures. Myopathies are hereditary (inherited from a mother or father) or acquired (from infection or underlying medical conditions). A patient will usually present with proximal muscle weakness and perhaps myalgia (muscle aches). An EMG/NCS can localize the disease process in such cases to aid diagnosis [3].

Focal Neuropathies occur when a single nerve suffers damage at a specific site along its course. An infinite number of possible focal neuropathies exist in the body, but the most common example is carpal tunnel syndrome. Carpal tunnel syndrome occurs when the nerve to the hand is squeezed at the wrist, causing numbness, tingling, and pain. An EMG/NCS evaluates the severity and location of such focal neuropathies [4].

This paper contains an introduction and general concepts, background of EMG signal physiology of signal, fundamentals of signal, measurement system of real EMG human muscle signals, and design of detection system taking the human arm as case study. Simulation results for all components of system design are discussed, and the graphical user interface (GUI) design is explained to demonstrate the simulations and present the program. Finally, the conclusion and suggestions for future work are given.

II. PHYSIOLOGY EMG SIGNAL

Electrical activity in the muscles arises from the contraction of muscle fibers, the structure of which is shown in Fig. 1. Each muscle fiber contains a bunch of myofibrils (long chains of contractile units). The myofibrils contain long chains of contractile units called sarcomeres, which contribute to the force exerted within muscles [8].

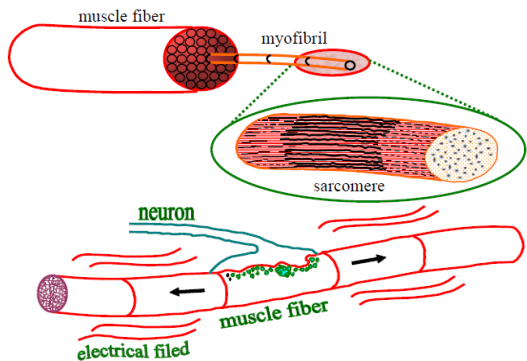


Fig. 1. Muscle fiber composition[8].

Each myofibril is chemically activated by local neurons, generating an electrical charge that moves up and down the myofibril, thus activating the chains of sarcomeres (Fig. 1). The charge motion generates an electromagnetic field that induces volume conduction, which enables the recording of an electrical signal both internally at the muscle and externally at the surface [8].

The detected waveform resulting from the depolarization of the wave propagating between the motoneuron and end plate is called the muscle fiber action potential (MAP). MAPs are not commonly seen in the general EMG literature because they are recorded using microelectrodes and cannot be picked up by non-invasive surface electrodes [16].

Muscle fibers contract in groups that are controlled by the central nervous system via nerve fibers (axons) transmitting the signal to the ending neurons. To simplify the analysis and mathematical interpretation of EMG, the smallest controllable functional unit of muscle fibers is defined as a motor unit (MU). The MU consists of a single motoneuron, its neuromuscular junction, and the muscle fibers that it excites.

EMG Characteristics

The wave shape of MU potentials is assessed based on the defined quantitative waveform features (Fig. 2).

Amplitude is determined by the presence of active fibers within the immediate vicinity of the electrode tip. Low-pass filtering by the volume conductor attenuates the high-frequency spikes of remote SFAPs. Thus, the MUP amplitude does not increase for a larger MU. However, MUP amplitude will increase if the tip of the electrode is located near a cluster of re-innervated fibers. Large MUP amplitudes are frequently observed in neurogenic diseases.

Rise time is an increasing function of the distance between the electrode and the closest active muscle fiber. A short rise time in combination with small MUP amplitude might therefore indicate that the amplitude is reduced because of fiber atrophy rather than a large distance between the electrode and the closest fiber.

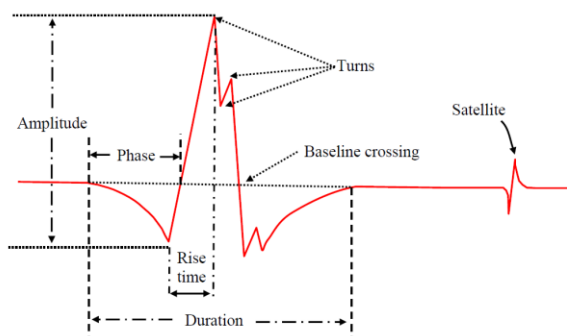


Fig. 2. Characteristics of an EMG signal [13]

Number of phases indicates the complexity of the MUP and the degree of misalignment between SFAPs. In neurogenic diseases, polyphasic MUPs arise because of slow conduction velocity in immature nerve sprouts or slow conduction velocity in re-innervated but still atrophied muscle fibers. Variation in muscle fiber size also causes polyphasic MUPs in myopathic diseases. To prevent noisy baseline fluctuations from affecting the count of MUP phases, a valid baseline crossing must exceed a minimum absolute amplitude criterion.

Duration is the time interval between the first and last occurrence of the waveform exceeding a predefined amplitude threshold, e.g., 5 μ V. The MUP onset and end comprise the summation of low-frequency components of SFAPs scattered over the entire pickup range of the electrode. As a result, the MUP duration provides information on the number of active fibers within the pickup range. However, the MU territory can be larger than the pickup range of the electrode. Thus, MUP duration does not provide information on the total size of a large MU. *Area* indicates the number of fibers adjacent to the electrode. However, unlike MUP amplitude, MUP area depends on MUP duration and is therefore influenced by fibers in a larger region than that of MUP amplitude.

Turns is a measure of the complexity of the MUP, much like the number of phases. However, a valid turn does not require a baseline crossing like a valid phase. Thus, the number of turns is more sensitive to changes in the MUP wave shape. To distinguish valid turns from signal noise, successive turns must be offset by minimum amplitude.

III. MEASUREMENT OF EMG SIGNALS

An EMG signal is obtained from the subject by either measuring non-invasively with surface electrodes or invasively with wire or needle electrodes. The measured signal is then amplified, conditioned, and recorded to yield a format that is convenient for answering the clinical or scientific question of concern. The measurement and recording of a complex analog signal, such as EMG, is a complex subject as the signals of interest are invariably very small (in the order of 10 μ V to 5 mV) [16].

In addition, the signals are usually found in combination with very large spurious signals from motion artifact, as well as induced voltages from nearby AC power lines, fluorescent lights, cell phones, and other electrical equipment, such as computers and monitors, all of which are potent sources of interference. As a result, both a quality EMG system and a versatile analog signal recording system are essential when planning anything more than the most casual of analysis functions [17].

A. Recording Systems

Three types of recording devices are commonly used: strip chart recorders, multi-channel analog tape recorders, and computer-controlled data recorders. In each case, the frequency response of the recording device must be at least equal that of the EMG signal being recorded. For surface EMG signals, the frequency response is generally considered to be 10 Hz to 500 Hz, whereas needle (fine-wire) recordings directly from the muscle may produce signals in the range of 2 Hz to 1,000 Hz [17].

B. EMG Electrodes

The EMG signal is measured either non-invasively with surface electrodes or invasively with wire or needle electrodes. Typical EMG signal levels are in the region of 400 μ V to 3 mV (depending on many factors). Thus, the measured EMG signal is almost always pre-amplified, amplified, and conditioned to yield a format that is most convenient for answering the clinical or scientific question of concern. The detection electrode for EMG is typically bipolar, and the EMG signal is amplified differentially. The waveform of the observed action potential will depend on the orientation of the detection electrode contacts with respect to the active fibers. EMG can be recorded from the skin surface or by placing an electrode directly within the subject's muscle, which this is usually referred to as a fine-wire recording [17].

Surface EMG is generally recorded with either passive or active electrodes placed on intact skin surface over the subject's muscle, whereas fine-wire recordings use a wire electrode that is inserted into the muscle by a trained (and, in most cases, licensed) professional. Each electrode type has specific advantages and disadvantages. As regards recording the EMG signal, the amplitude of the MU action potential depends on many factors, including the diameter of the muscle fiber, the distance between active muscle fiber and the detection site (adipose tissue thickness), and filtering properties of the electrodes themselves. The objective is to obtain a signal free of noise (i.e., movement artifact, line frequency interference, etc.). Therefore, the electrode type and amplifier characteristics serve a crucial function in obtaining a noise-free signal [18,19].

Several pre-amplifier characteristics need to be considered when recording either surface or fine-wire EMG signals, as shown in Fig. 3.8. The first consideration is the signal-to-noise ratio of the preamplifier, which can be quoted in two different ways: the ratio of the wanted signal to the unwanted signal or as a simple noise level, usually with respect to the input signal. In either case, signal-to-noise ratio is a measure of the quality of the amplified signal; high signal-to-noise ratios and low noise figures both indicate a high-quality pre-amplifier in most cases. Miniature EMG preamplifiers at the site of, or including, the EMG electrode are almost invariably the best at providing a very large signal to noise ratio [20].

IV. DESIGN OF GUI PROGRAM FOR THE DETECTION OF MUSCLE DISEASE

The GUI is designed to be simple and user friendly. A GUI Network/Data Manager window should first be brought up. This window has its own work area, separate from the more familiar command-line workspace. Thus, when using the GUI, the GUI results can be exported to the (command-line) workspace. Similarly, results can be imported from the workspace to the GUI.

Flow chart of design program

The flow chart for the processing of this work, starting with measurement of real EMG signal and ending with the decision on detected the muscle diseases is as follows:

The neural network (NN) package for the detection of muscle diseases consists of three main stages:

- Structure of NN
- Identification of NN

- Detection of muscles disease by NN
- In this work, the processing of N.N. is done by using the package that is explained in detail in Ref. [12].

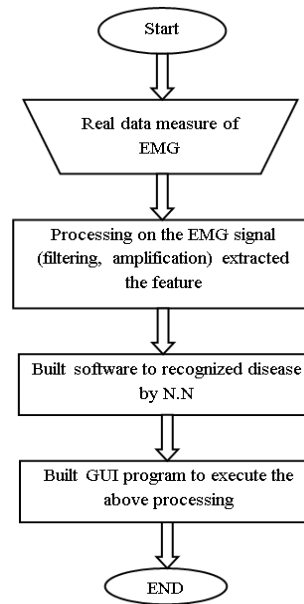


Fig. 3. Flow chart for all system design

V. DESIGN GUI FOR THE DETECTION OF MUSCLE DISEASE

This package consists of 18 main windows, starting with the first window, which is called the "Main window of GUI," and ending with the "Exiting window," as shown in Fig. 4. This design consists of 18 windows that can be divided three groups: the first group executes the instruction for call program was writing by using MATLAB editor. This program is used for signal processing, identification of NN, and detection of muscle diseases. The second group comprises windows of the GUI package used for displaying the help files that explain the basic idea and fundamental concepts. The third group is used to manage the GUI package and includes the exit and starting windows



Fig. 4. GUI windows for system design

The starting window of GUI is shown in Fig. 4, which explains the idea of the work as well as how to start the research and some problems in this system. The *next* button is used to move on to the structure of the system window, as shown in Fig. 5(1–5).

The system has two main parts. One explains the current this division, whereas every button will move to a new window of the system. The properties of every part are shown in Fig. 5(2). The package stores photos and movies of some selected subjects, as listed in Fig. 5(3–5).



Fig. 5(1–5). Structure of the simulated system

VI. SIMULATION MEASUREMENT OF READ EMG SIGNALS

The next step in the GUI is EMG signal measurement, which has two main sources for real EMG signals and EMG characteristics. The GUI is shown in Fig. 6(1–4).

The block diagram for measuring real signals is shown in Fig. 6(2). In Iraq, many problems are encountered in a real measuring system, such as that in the educational hospital in Kiadymia, Baghdad Medical City, AL Yromook hospital, and some private clinics.

The EMG data measured by using the device in AL Ramadi city are stored in the format (*filename.TRC*) [Fig. 6(3)]. These data can be read and collected by the program EMG lab. The practice data from the hospital are arranged by table for every muscle with three cases: no resistance (no activity of muscle), low resistance (mild), and high resistance. The real value for muscle parameters can be obtained by studying the anatomy of muscles in detail.

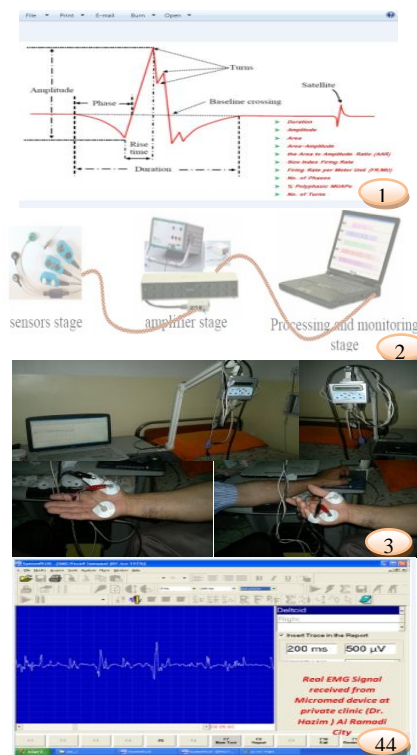


Fig. 6(1–4). EMG characteristics and measurement of real EMG signals

To start the process of the detection of muscle diseases, we go to step three in the first window of the designed GUI, as shown in Fig. 7(1). The start button in Fig. 5(2) is selected to choose real EMG signal samples. These samples are analyzed by EMG lab, and then the disease is detected in NN, as shown in Fig. 7(1). To obtain the data on EMG signals, a specific human arm muscle must be selected. These data are calculated by selecting the specifications of the normal human body.

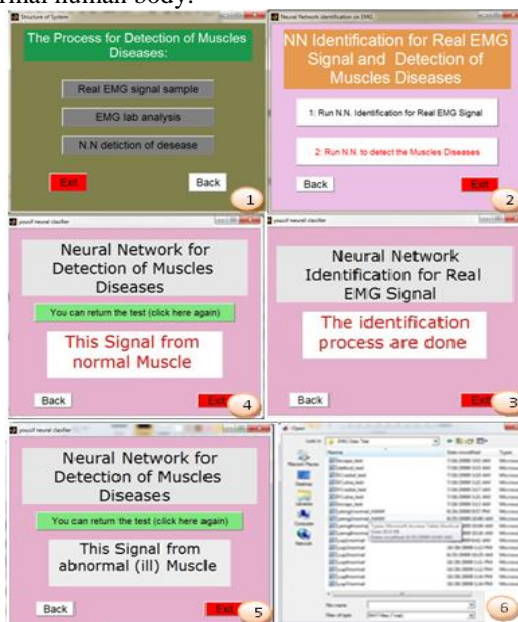


Fig. 7(1–6). Window for the detection of muscle diseases

The applied of NN called by the GUI window is shown in Fig. 7(2). The identification process is based on the choice in terms of collecting the data base for NN reorganization [Fig. 7(3)]. After the identification process, the final stage is the testing window to obtain the final decision on the selected signal. The project can be completed by exiting, as shown in Figs. 7(4–6). The “exit window” is shown in Fig. 4(2). All windows from 1 to 17 have the option for exit and for returning to the same exit point.

VII. CONCLUSION

From the results obtained through real measurements and simulation with analysis, the following conclusions can be drawn:

- a. High-accuracy NN detection was used to distinguish human arm muscle EMG signals. Muscle diseases were detected based on EMG signals using FRBP-NN, which is an efficient method because of its simplicity and accuracy. This method can be implemented in many medical applications, such as the use of artificial limbs and high-accuracy robot applications.
- b. The design of the proposed package is based on the GUI technique, which gives the capability to connect all three parts under consideration, simulate individual parts by transportation among them, and finally present the three parts simultaneously as one animation system. Moreover, this package includes instructions with explanations presented in notes and graphs, thus enabling this package to be used as an educational tool for human muscle diseases detection.
- c. Real-time monitoring and analysis of EMG signals, extraction of all important features from captured EMG required for correct diagnosis of different neuromuscular diseases, and patient data management enable remote clinicians to follow patient progress. The developed GUI can be easily modified to suit clinician needs.

ACKNOWLEDGMENT

Special thanks are due to University of Anbar – Iraq / Renewable Energy Research Centre for supporting me with the work with Grant No. RERC-PP21

REFERENCES

1. A. K. G. Murphy, “Effective Information Display and Interface Design for Decomposition-based Quantitative Electromyography”, M.Sc thesis, University of Waterloo, Canada, 2002.
2. N. BU, “ EMG-Based Motion Discrimination Using a Novel Recurrent Neural Network ”, Journal of Intelligent Information Systems, 21:2, 113–126, 2003.
3. Toshio Tsujii " Pattern classification of time-series EMG signals using neural networks", international journal of adaptive control and signal processing , 2000.
4. Madeleine M. Lowery, " A Multiple-Layer Finite-Element Model of the Surface EMG Signal", MAY 2002.
5. O. Bida, “ Influence of Electromyogram (EMG) Amplitude Processing in EMG-Torque Estimation ”, M.Sc Thesis , worcester polytechnic institute ,Electrical Engineering , January 2005.
6. M. B. I. Reaz, " Techniques of EMG signal analysis detection, processing, classification and applications", March 23, 2006.
7. Anne K. G. Murphy, " Effective Information Display and Interface Design for Decomposition-based Quantitative Electromyography, thesis, 2002.
8. Luca Mesin and Dario Farina, " Simulation of Surface EMG Signals Generated by Muscle Tissues With Inhomogeneity Due to Fiber Pinnation", Sep. 2004.

9. Andrew Hamilton, " Physiologically Based Simulation of Clinical EMG Signals", FEBRUARY 2005.
10. M. Z. Al-Faiz, Yousif. I. Al-Mashhadany, “Human Arm Movements Recognition Based on EMG Signal”, MASAUM Journal Of Basic and Applied Sciences (MJBAS) Volume 1 Issue 2, PP 164-171, (September 2009).
11. Yousif. I. Al-Mashhadany, "Measurement of human leg joint angle through motion based on electromyography (EMG) signal", The Engineering Conference of Control, Computers and Mechatronics, ECCCM2011, university of Technology, 30-31, January, 2011
12. Yousif I. Al-Mashhadany, “Design and Analysis of Virtual Human Arm Driven by EMG Signal”, BOOK , ISBN: 978-3-8433-7973-1, 2011, LAP LAMBERT Academic Publishing GmbH & Co. KG, 2011
13. Yousif Al Mashhadany, Nasrudin Abd Rahim, “Real-Time Controller for Foot-Drop Correction by Using SEMG Sensor”, Proc IMechE Part H: J Engineering in Medicine, 227(4) 373–383. Jan, 2013,(Q2 ISI Journal)(I.F.=1.208)
14. N. A. Shrirao, N. arender, P, Reddy, “ Neural network committees for finger joint angle estimation from surface EMG signals”, BioMedica l Engineeri ng OnLine 8 :2, 2009.
15. V. R . Mankar, A. A. Ghatol, “Design of Adaptive Filter Using Jordan/Elman Neural Network in a Typical EMG Signal Noise Removal ”, Hindawi Publishing Corporation Advances in Artificial Neural Systems Volume 2009, Article ID 942697, 9 pages doi:10.1155, 2009.
16. O. A. Alsayegh, “ EMG Based Human Machine Interface System” , IEEE Transaction of Biomedical Engineering, 0-7803-6535-4/00/ pp 925-928, 2000.
17. M. M. Lowery, N. S. Taflove, “ A Multiple Layer Finite-Element Model of the Surface EMG Signal ” , IEEE Transaction of Biomedical Engineering, Vol. 49, no.5, PP 446-454, May 2002.
18. L. Mesin, D. Farina, “ Simulation of Surface EMG Signals Generated by Muscle Tissues with Inhomogeneity Due to Fiber Pinnation ”, IEEE Transaction on Biomedical Engineering Vol. 51, no. 9, PP 1521-1529, September 2004.
19. Motion Lab Systems, Inc, “A software user guide for EMG Graphing and EMG Analysis EMG Analysis”, Updated Thursday, February 26, 2009.
20. EMGLAB software Version 0.9 User’s Guide, “The MathWorks, at www.mathworks.com, May 2008.