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REVOLUTIONIZING MUSCLE MONITORING: SURFACE MULTI-PURPOSE LOW POWER WIRELESS ELECTROMYOGRAPHY (EMG) SYSTEM DESIGN

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ABSTRACT: Bioelectric signals from the body may now be collected and analyzed in real time because to advancements in electronics, technology, signal processing, and computing. Different challenges must be solved depending on the signal's frequency and qualities. Furthermore, data from numerous sources must be transmitted simultaneously, at a frequency of up to 1 kHz. Another problem is appropriately detecting the bioelectric signals that are being transmitted. These signals can have amplitudes of tens of microvolts, therefore they must be extremely sensitive with minimal noise interference. These characteristics contributed to the development of a low-power wireless Electromyography (EMG) data exchange system capable of meeting these stringent requirements. This effort included the development of a hardware system for processing EMG analog signals, as well as computer-based software to support it. Many large issues have been solved in the course of developing analog circuitry capable of processing EMG signals. One of the issues is bias DC current, which causes artifacts and noise. By plotting the gathered EMG data on graphs and using computer-based tools, the user may clearly see and judge it. The findings of this study indicate that a surface electromyography (EMG) device can be utilized to obtain EMG data. This information can then be applied to movement analysis, sports medicine, rehabilitation, and medical tests. The findings indicate that the proposed system delivers and receives signals appropriately, with no information loss.

KEYWORDS: Electromyography, wireless, Biceps brachii muscle, surface electrodes.

1. INTRODUCTION

Real-time recording and analysis of bioelectrical data from humans is now possible thanks to advances in computer technology, signal processing, and electronics. To measure bioelectrical impulses originating from humans, the measuring instrument must meet particular criteria. Data transmission rates must be fast due to the simultaneous usage of multiple measurement channels and a typical sample frequency of 1 kHz or higher. Typically, the full bandwidth of the measurement signal must be transmitted. However, modern low-power wireless data transfer technologies are capable of meeting this tight requirement.

Electromyography (EMG) is a technique for quantifying changes in electrical potential at specific anatomical regions on a muscle. These locations are fitted with EMG devices. Muscle contraction produces electrical impulses that indicate the state of the muscles. When a muscle contracts, it sends an electrical signal to the brain. The amplitude of the electrical discharge produced when muscles contract is influenced by the direction of muscle tension, the force exerted to move the joint, and the velocity of muscle contraction.

Francesco Redi was one of the first scientists to study, synthesize, and analyze EMG signals in 1666. He created a DVD that shows how the electric ray fish's tremendously powerful muscle generates electricity. Walsh did not demonstrate for a long time after the occurrence that the muscle of an Ele fish could generate an electric spark. In 1792, A. Galvai did studies on the relationship between electricity and muscle spasm. Dubios Raymond discovered in 1849 that it is possible to electronically record muscular contractions. Marey, who discovered the electrical signal of muscle contraction over 50 years ago, developed the name "electromyography" to describe his discovery. He was the first to record the signal.

In 1922, Gasser and Erlanger used a monitor to display an electromyographic (EMG) signal emanating from a muscle. Nonetheless, the failure to see and interpret the EMG signal was attributed to its inherent properties as well as interference from noise. From the 1930s to the 1950s, substantial advances in electrode technology made it easier to collect electromyography (EMG) data. Manufacturers and researchers developed a better knowledge of how muscles work as a result.

After 1960, physicians began using surface electromyography electrodes to stimulate muscles. Hardyck and his study team were among the pioneers who used this method in 1966. In the 1980s, a new generation of EMG devices featuring microprocessors was released. These devices' popularity grew due to their low price and ease of use. Over the last fifteen years, research and advances in EMG signal technology have led to a better understanding of both muscle function and EMG signal functionality. When tasks require changes in direction and velocity, wireless EMG is better than cable EMG.

The most contemporary EMG equipment includes portable technology like Bluetooth and Wi-Fi. This gives users of PC-based systems more freedom when they are away from their device. Currently, electromyography (EMG) signals can be detected and transmitted from the body to a computer without being physically connected for analysis, processing, or recording.

Electrical electromyography (EMG) impulses from muscles, like other biopotentials in humans, are rather modest in intensity. The EMG device's amplifier amplifies EMG signals to a threshold voltage (±5 volts) for computer analysis with a data collection instrument (DAQ). Before being communicated to a computer, analog EMG data must be transformed to digital format. As a result, when collecting EMG data, it is necessary to consider a variety of parameters, including the risk of signal distortion due to noise and abnormalities. Excessive direct current (DC) current can potentially disturb the EMG signal. Establishing a dependable point of reference is another key objective that must be met. EMG installations are unneeded in clinical settings due to their high cost, technical assistance needs, and dependency on staff skilled at operating complex configurations. Because of these issues, EMG technology must be included into the normal physical diagnostic test setup.

The goal of this project was to create an electromyography (EMG) configuration system capable of detecting signals from the biceps brachii muscle. Furthermore, the system provides the necessary technical assistance for data processing and analysis. The EMG gadget is used to collect biceps muscle electromyography (EMG) data. In addition, the three surface electrodes are used to record EMG signals from the targeted muscle. While EMG has long been used by researchers in a variety of areas, there is a lack of information in the literature about the best electrode placement locations. Typically, the electrode is carefully positioned in the center of the targeted muscle using skillful wire manipulation. For these conditions, standards similar to those used for diagnostic EMG must be used. Despite this, the ideal electrode site for surface electromyography remains unknown. Some people believe that the motor point, which corresponds to the area where muscle activation is most easily achieved, should have the most powerful electrical potential. Parallel alignment of the electrode lines with the muscle fibers is preferred than perpendicular alignment. The ideal distance between electrode centers is between 2 and 10 mm, taking into account the duration of electrical events and the rate of charge transfer across the electrodes. It is necessary to evaluate the differences between proximal and distal muscle fibers with extreme caution. To ensure an optimal recording contact, one of the linear dimensions must be at least half the distance between the two electrodes. It is crucial that the size and resistance of bipolar recording contacts match as closely as possible. A set of regulations governs the selective approval or recording of electrical potentials.

The chemical electrode transducer can detect muscle contractions. Although the electrodes used in EMG come in a variety of forms and sizes, they all communicate through a metal electrolyte contact. The device includes a metallic electrode and an electrolyte, which can be body fluids that come into contact with the implanted electrode, an electrolytic solution or substance when surface electrodes are used, or both. The movement of ions in distinct types of tissue and the passage of electrons in the recording device are switched at the electrode-liquid interface. An electrode is an effective transducing element because it can evenly distribute ions and electrons. This prevents the creation of charge gradients at the electrode-electrolyte interfaces.

To get an electromyography (EMG) signal from the biceps muscle, the first two electrodes are placed across it in this task. The third electrode is placed in the cubital area of the dorsiflexor brachial muscle on the unused arm. Using this electrode, the body standard voltage is determined. The biceps muscle was chosen as the focus of the project demonstration because it is easily accessible and visible. The right biceps underwent a voluntary maximum isometric contraction. The EMG amplifier must have enough area to hold two surface EMG electrodes. The data acquisition (DAQ) device sends data to the computer to help analyze and comprehend the information collected from the EMG amplifier. It is encouraged to use the basic components of the EMG system, and the data collection method is thoroughly explained.

2. METHODS

This method employs surface electrodes to capture electromyography (EMG) data from many muscles in the body, including the Biceps brachii. These signals are wirelessly transmitted to a personal computer using isometric contractions at a specific elbow angle. EMG data are necessary to evaluate muscle movement. The insertion of electrodes into distinct muscle regions results in an electromotive potential difference. An electromyography (EMG) signal indicates that this induces electrical activity in the muscle. The wireless EMG device has three consecutive steps: The electromyography (EMG) signal is then acquired and transmitted using radio frequency (RF) wireless technology. The final stage is to collect it in order to conduct more research on it. Figure 1 shows the block diagram of the proposed wireless electromyography (EMG) system. The analog to digital converter (ADC) converts the recorded EMG signals into a digital format. A Data Acquisition (DAQ) apparatus transmits data to a computer for medical diagnosis and produces a graphical representation of the data.

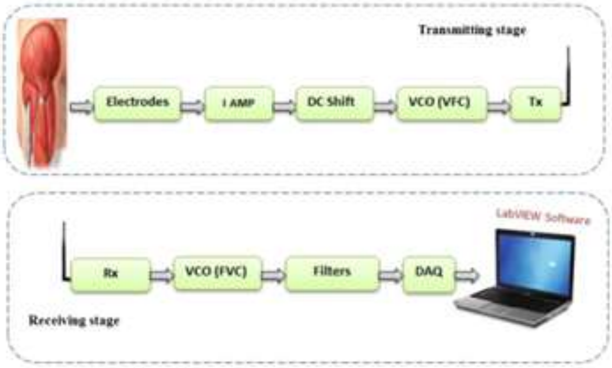

Fig 1: Block diagram of the proposed overall Wireless Electromyography (EMG) system design.

Wireless EMG System

EMG signals are collected by placing electrodes on the muscle's epidermal surface and detecting sensitive spots. The EMG signals from the biceps muscle were obtained using three silver-surface electrodes. The first electrode is applied to the epidermis immediately above the middle of the muscle being investigated. The sensor will be referred to as "mid-muscle." Following that, a second electrode is put before the muscle portion. This device will be referred to as a "terminal muscle sensor". Finally, the third electrode is placed on a bony area of the body close to the muscle group. Figure 2 indicates the precise position of the reference electrode. The core communication system consists of the following steps, in that order:

The information signal is directed to the transmitter section, which prepares it for delivery. An emitter alters the configuration of a carrier signal, amplifies it, and transmits it across the channel. Figure 3 depicts the transmitter's circuitry.

The channel describes the path of modulated data as it approaches the receiver. Radio waves and other forms of communication travel via air.

The receiver is a subsystem component that accepts and processes channel signals in order to obtain information signals. The listener must be able to demodulate in order to obtain the data. This involves extracting the carrier signal, amplifying it for processing, and distinguishing it from other signals on the same channel; this is referred to as "tuning." Following that, the data is prepared for receiving, as illustrated in Figure 4 (which shows the receiver circuit).

Fig 2: Electrode placement.

Electronic devices using the standard TTL level (±5 volts) cannot directly retrieve EMG data due to insufficient voltage. Signal amplification is required to increase signal intensity to the TTL level in this situation. The AD524 amplifier is chosen for its extraordinarily high Common Mode Rejection Ratio (CMRR). Furthermore, the output signal is represented by the voltage difference between the two input signals, disregarding any low-level signal confusion in either input. The buffer amplifier has a high input impedance to prevent voltage loss and maintain a constant voltage across the wires. Thus, there is no loss, and the voltage at the differential sources remains constant.

The shift amplifier converts enhanced EMG data to TTL (±5 volts) and splits it into positive and negative components before sending it to the computer. EMG signals are amplified and sent to the phase-locked loop (PLL). A voltage-controlled oscillator (VCO), two distinct phase comparators, a common comparator input, and a signal input amplifier are all present [15]. The HEF4046B circuit uses a phase-locked loop. The SHY-J6122TR TX/RX 433 MHz Modules can perform two functions: sending and receiving. These two components function as a transmitter and receiver. They can transmit at 1W (10m) with a frequency of 433.92 MHz and a supply voltage of 5V.

The TLB 433 2.5N antenna operates at 433MHz and is vertically polarized. The maximum power capacity is 50W, and the input impedance is 50Ω. A vertical electrical contraption 45 mm tall and weighing 5 g serves as a radio receiver or emitter, converting electrical currents from radio waves in space. Before uploading EMG data to the computer, a second-order or two-pole filter network is created by joining or cascading two first-order low pass filters.

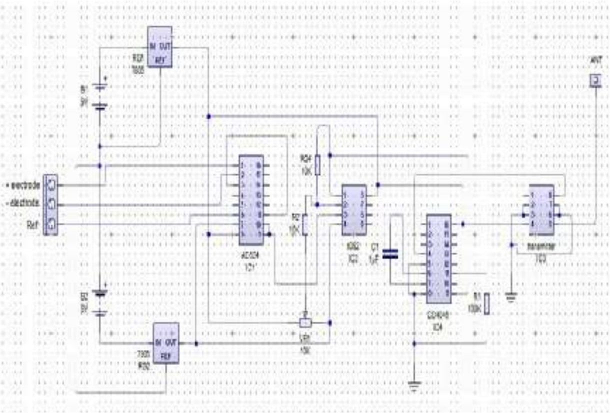

Fig 3: Circuit Diagram of Transmitting stage.

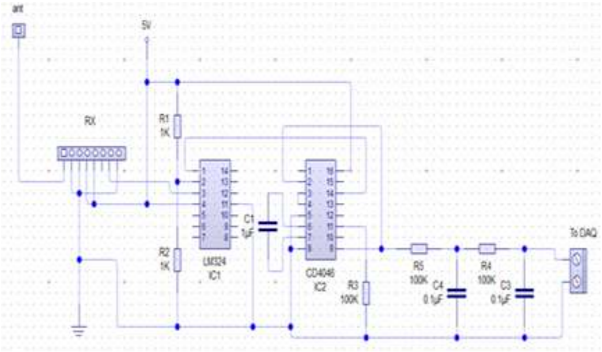

Fig4: Circuit Diagram of Receiving stage.

Data Acquisition (DAQ)

The purpose of data capture is to measure voltage, current, temperature, pressure, sound, and even voltage. PC-based data collection combines a computer, special software, and modular devices to collect data. Each data collecting system's primary function is to collect, process, and display data. However, each system's requirements may differ based on its intended purpose. A data collection system is made up of several components, including signals, sensors, actuators, signal conditioning, data capture devices, and application software. Data acquisition (DAQ) is utilized to collect information from real-world events for this investigation. After being transformed into digital signals, they are investigated, presented, and saved as EMG data. When compared to a standard flash analog-to-digital converter (ADC), it is much cheaper and consumes far less energy. Figure 5 provides a more detailed look at how the DAQ operates.

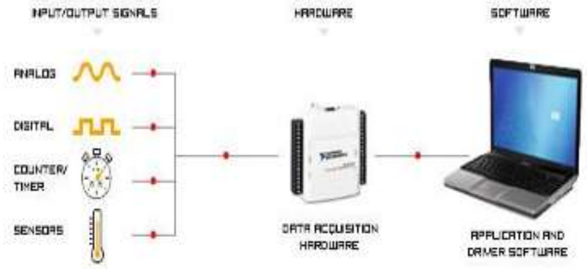

Fig 5: The DAQ system.

National Instruments' portable DAQ (NI USB-6008) is a low-cost, flexible I/O device. It connects to the circuit by USB and can buffer signals, provide +5V power, display signals in real time, and switch between analog and digital signals.

Most DAQ boards are installed in computers with fast data lines, such as the PCI bus. The USB connector on the IniLab1008 connects to a PC. The fastest data transfer rates between the microprocessor and memory are limited by the PC motherboard's speed. These rates might vary from 20 MHz to 40 MHz. Sample velocity and resolution are two of the most critical criteria influencing how effectively a DAQ card performs. We obtained a clear signal using wireless skin electrode electromyography (EMG) and processed it using several LabVIEW EMG signal processing methods such as frequency spectrum analysis, normalization, integration, Root Mean Square (RMS), and linear envelop.

Raw Electromyography Signal

When the random signal from the skin electrodes is activated, it is referred to as the "raw EMG signal." To ensure that the study is comprehensive, the raw signal must be carefully monitored for any weird or unusual activity. That manner, the inspector can identify and eliminate any major issues or bothersome areas of the signal. The ergonomist should be aware that nominal data refers to on-off switches, whereas ordinal data refers to the amount of action. When investigating ergonomics, the sensitivity levels and amplifier power of recording devices are critical in determining what may be learned. When looking at EMG records with simply raw data, there is no clear instruction or device settings, thus a lot of judgment is required. This data structure is not particularly useful for obtaining information regarding muscular strength or weariness. Figure 6 illustrates how the raw EMG data was handled. Following that, the data is examined to obtain an approximate figure that can be utilized for advanced or statistical analysis.

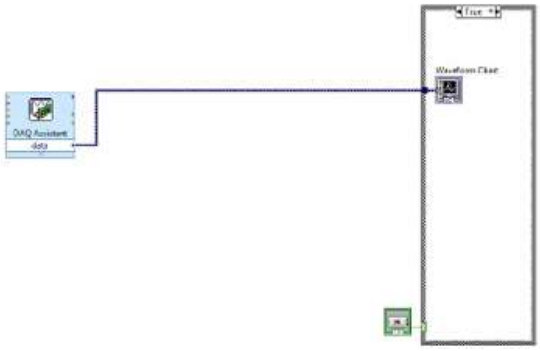

Fig 6: Raw EMG signal processing.

Normalization

It may also be required to standardize the timeframe for the project under consideration. It is feasible to create an action that occurs repeatedly with a force of 100 Newtons each time. This method simplifies the comparison of data sets with slightly different timestamps. This type of normalization has been used to study walking behaviors and the loads placed on the back. When Arborelius and his colleagues investigated how much stress was placed on the shoulder joint and how much muscular activity was required to lift a box, they calculated each job as a ratio of working cycles. Figure 7 shows how the EMG data is adjusted.

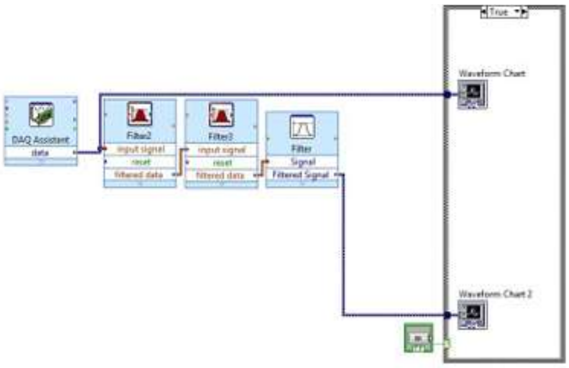

Fig 7: The normalization processing of EMG signals.

Integration

To make the integration process work, you must first employ an integrator, then filter and rectify the waves. Integration adds up the energy of all the messages by combining their constituent parts. The signal that has been processed indicates the size, cadence, and range of active motor units. It is impossible for the integration process to distinguish between motor units and objects. Noise is a major issue while collecting contractions at low force levels. When examining modest force level contraction, durations can detect an unusually significant quantity of noise. Figure 8 illustrates how the EMG data is handled all at once.

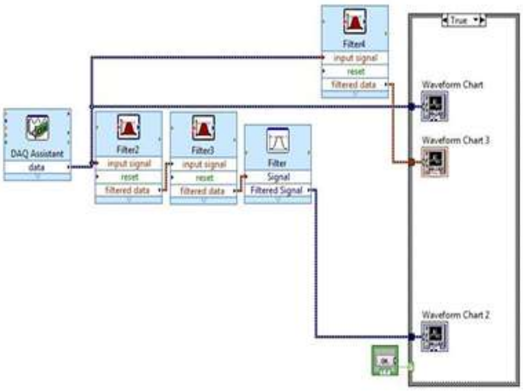

Fig 8: The integration processing of EMG signals.

Root Mean Square (RMS)

The root-mean-square (RMS) voltage of an oscillating current indicates its actual value. The true RMS value of a myoelectric signal indicates how strong the signal's electricity is. To calculate the RMS number, you can use a digital computer, thermocouple, heavily damped voltmeter, or ballistic galvanometer. A nonlinear detector may be used instead of a linear detector. The power spectrum has a direct relationship with the signal's root mean square (RMS). The curvature of the curve indicates how well the myoelectric messages perform. The power number is equal to the integral of the spectral curve. The square root of total signal power indicates how loud the signal is. The root mean square (RMS) is clearly linked to tension during a brief isometric contraction. Figure 8 depicts how the RMS views the electromyography (EMG) data and how this link is displayed.

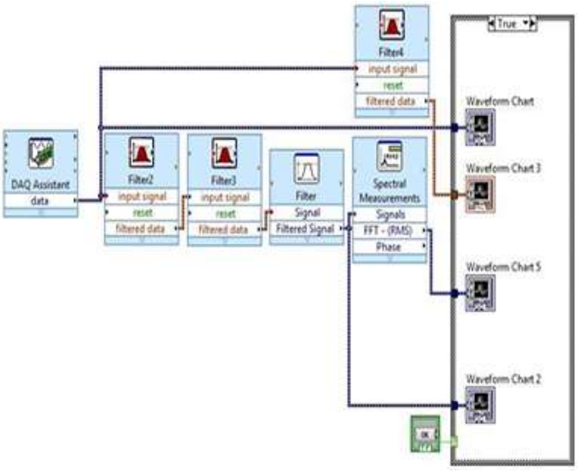

Fig 8: The RMS processing of EMG signals.

Frequency Spectrum

The square of the fast Fourier transform (FFT) magnitude is used in this work. The middle frequency remains constant at most levels of contraction force. However, at low levels, it increases in proportion to the force. It has been questioned whether changes in the myoelectric signal spectrum can accurately anticipate muscle fatigue. The study's major purpose is to discover a link between frequency analysis based on zero crosses and the amount of shoulder and neck ailments reported by assembly line workers. Figure 9 depicts how EMG data is handled in the frequency domain. Even if alternative approaches exist, the results are promising, implying that this one could be valuable for ergonomic study at work. However, this type of investigation may not receive adequate attention.

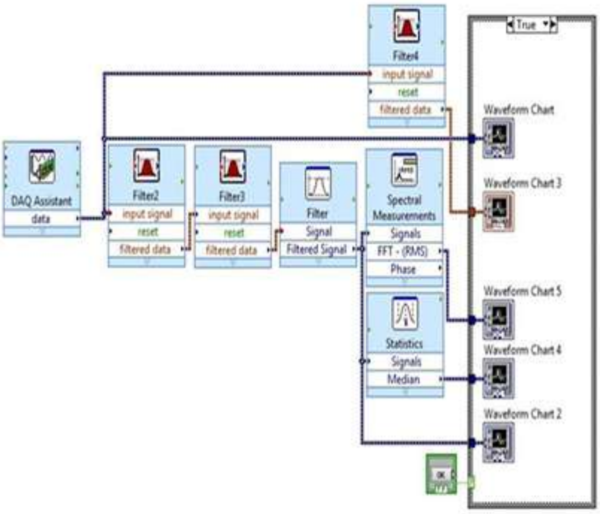

Fig 9: The frequency spectrum processing of EMG signals.

Linear Envelope

Using a linear envelope, one may describe the temporal evolution of myoelectric activity in a muscle.

Implementation

Wireless EMG device is best suited for quickly gathering and interpreting EMG data. Accurate signal detection and analysis are crucial for determining a software product's functionality. This work was reviewed with LabVIEW on the Windows operating system. Additionally, the LabVIEW programming language was used in its creation and execution. Our graphical user interface (GUI) provides access to a wide range of tools for producing visual results.

A simple graphical user interface was created using LabVIEW. The software provides access to a visual programming language that is extremely useful for both hardware integration and general-purpose programming. Figure 6 shows an early inspection of the graphical user interface (GUI). The graphical user interface (GUI) allows users to ascertain a patient's "ID" and select the most effective bandpass filters for them.

3. RESULTS

The Electromyogram (EMG), which analyzes amplitude and frequency fluctuations, can be used to quantify and categorize the degree of electrical activity associated with a certain muscle tension. The myoelectric signal is affected by the frequency and magnitude with which a muscle's motor units fire. When more force is necessary, additional motor units are usually summoned, and those that are functioning at full capacity discharge more frequently. In contrast, not every muscle responds in the same way to this substantial stimulus. Changes in a muscle's discharge rate and demand can indicate strength or weariness. This paper demonstrates several ways that an ergonomist can use to evaluate or comprehend myoelectric activity for a range of work-related goals.

Before being represented numerically, the data produced from the electrical signal passes through a series of reductionist methods. The method used is dictated by the study's purpose, or rationale for data collection. The interpretation of the electromyography (EMG) data is primarily responsible for the relationship between muscle activity and task performance. The myoelectric signal conveys two key pieces of information: 1) the degree of muscle activity in comparison to its relative strength, and 2) a binary signal signifying muscular activity or inactivity. By using the right normalization technique, the ergonomist can obtain a valid estimate of muscle performance. Based on the above data, one may use an observation system or a simple event tracker to determine: 1) The duration of muscular action. 2) The era in which the most activity happened. 3) Muscle contraction pattern in response to agonist and antagonistic stimuli.

The unprocessed EMG signal is the foundation on which all approaches rely to determine the importance of myoelectric activity originating in muscles. Even if extra signal processing is used, the ergonomist must monitor the unprocessed signal to identify and resolve any problems that may develop, especially if they are trying to quantify spikes or achieve other specific goals.

In the past, viewing the unprocessed EMG signal output was probably the most common way for assessing EMG data. With an oscilloscope capable of detecting shifting gains and sweeping vibrations, an observer with the necessary expertise and training could examine the raw EMG signal quickly and clearly.

Observers should be able to distinguish between active and relaxed muscles using the raw signal. Activity can be quantified on a scale of zero to five, with zero indicating little activity and five indicating a lot of activity. It can also be divided into personal categories, such as "marked," "nil," "negligible," "mild," "moderate," "nil," or "extremely marked." Figure 7 depicts the graphical user interface (GUI) of the proposed wireless electromyography (EMG) system, which displays processed and stored EMG data.

Fig 10: The GUI of the proposed Wireless EMG system with recorded and processed EMG data.

4. CONCLUSION

Long-term monitoring of important physiological signals has been shown to be a highly effective tool for measuring patient health and performance. The goal of this project is to create a wireless electromyography (EMG) device that can communicate data wirelessly from the recorder to the sensor. This will help to avoid the complications that come when lead wires are used in standard arrangements. This essay demonstrates the use of a surface electromyography (EMG) device. To assemble the device, three phases are required: data acquisition, computer EMG (GUI) capture software, and analog signal processing.

The goal of the EMG analogue signal processing stage is to improve the EMG data from a single biceps muscle. The EMG analog signal processing stage consists of five basic components: the instrumentation amplifier, the shift amplifier, the low pass amplifier, the surface EMG electrodes, and the whole wireless transmitter and receiver. The EMG amplifier's input devices are EMG electrodes located on its surface. The differential instrumental amplifier stabilizes irregular and weak EMG impulses to a consistent TTL level, allowing for easier subsequent processing. Low pass filters allow one to choose assign the required signal bandwidth for a given job. Wireless technology allows messages to be transmitted and received without causing data deterioration while in transit.

The 12-bit A/D converter built into the DAQ process is used to convert EMG data into digital signals. The DAQ's subsequent role is to transmit the digitalized EMG signal using the provided USB Serial connection module.

LabVIEW software was designed as an EMG capture graphical user interface to make it easier to read recorded EMG data. The application performs basic functions such as obtaining saved EMG data, applying filters, and doing analyses on it. The program also offers a sketching tool for visualizing EMG data as graphs. This is Phase I of the muscle identification process, which happens while the body is in motion. The second phase of our research will concentrate primarily on the interactions between agonists and inhibitors.

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