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# Diagnosis of Hand Tremor from EMG Sensors

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***Abstract*— Parkinson's disease (PD) initially affects on motor activities of the patient. The symptoms of the disease include tremors, muscular rigidity, changes in gait, and complications in speech. In this paper, the experimental procedure for the acquisition of EMG and accelerometer data is explained. From the data, tremor frequency is evaluated. Tremor is an involuntary shaking of the body or the limbs which is considered as an early symptom of Parkinson's disease. EMG instrument, sensors, selection of muscles in the study, data acquisition procedure, analysis of EMG and accelerometer signal are discussed in this paper. Then the signals were analyzed in the frequency domain to assess tremor frequency in the hand. Since the signals were taken from the underlying muscles of the skin, the results are relatively accurate than indirect methods of hand tremor assessment.**

***Keywords*— Parkinson's disease; tremor frequency; ECG acquisition; muscular rigidity***

## I. INTRODUCTION

Motor movement in Parkinson's disease (PD) patients affects due to cell death in the motor cortex of the brain [1]. A neurotransmission chemical, called dopamine plays an important role in the coordination of motor activity and memory. The most obvious symptom of PD is tremor. Generally, tremor may be described as non-voluntary controlled rhythmic oscillations of body or limbs at specific frequency and amplitudes. Parkinsonian tremor is of two kinds; resting tremor and postural tremor. Resting tremor of hand has a typical range frequency of 3-7 Hz. The motor cortex controls specific parts of the body such as hand, thumb, face, tongue, etc. Fig. 1 shows the position of the motor cortex in the brain and its coordinating parts. When cellular death is rapid, activities of related body parts get hampered. Neuroscientists are still trying to understand the cause of cell death from their on-going research. Each motor unit from the mid-brain region is connected with the skeletal muscle through the spinal cord. Hence, the connectivity between the central nervous system and skeletal muscles establishes the intended human movement. Fig. 2 show the connectivity between the central nervous system and the skeletal muscle. The skeletal muscle is one of the three major types of muscles of the human body constituting about 50% of the body weight and is the largest signaling pathway in the body [2]. The smallest unit in the muscle provides a pathway for an electric impulse that makes communication possible between the brain and skeletal muscle. The smallest unit is called a motor unit (MU). There are several techniques to synthesize these signals. These muscles move the respective body parts by contracting against the skeleton. Voluntary movement of body parts thus depends upon the activation of skeletal muscles.

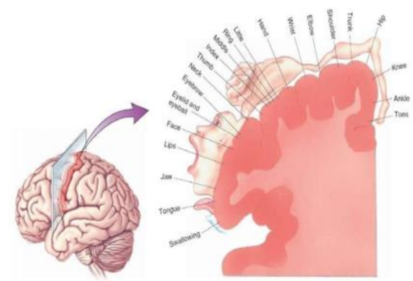

Figure 1 Motor cortex and the associated parts (Web Source).[3]

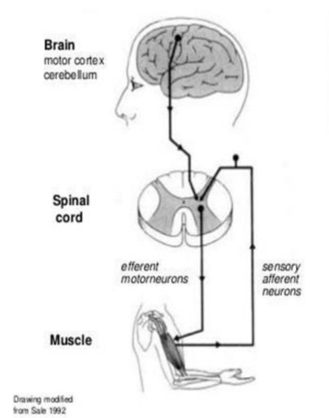


Figure 2 Muscle connectivity between CNS and skeletal muscle of the hand.[4]

In the human body, the arm extends to the hand and the complex abilities of the hand make humans unique. The upper limb of the body, existing in pair, has three segments, upper arm, forearm, and the hand. The human hand is capable to do a variety of functions with the help of muscles stretched over the arm. Thus, the hand enables us to do many of our daily activities including motor movements. Fig. 3 shows the superficial muscles of the hand and arm. Any muscular activity is triggered by specific ions (sodium, potassium, and calcium) that are available across the cell membrane in the muscle. During this process, a series of action potentials are produced across the membrane. The potentials available in the form of the signal can be measured from the skin surface of the limb which is called electromyography (EMG). Measurement and analysis of EMG signals from the muscle surface indicates the motor activity of that limb.


Figure 4.3 Anterior view of muscles in the human right hand.[5]


Figure 4 DELSYS Trigno Wireless EMG instrument showing the base station and a sensor.

EMG is a technique used to record muscle information acquired from the action potential. EMG Recording and analysis of EMG signals have tremendous applications in clinical research, rehabilitation, and biomechanics fields. EMG signal is a biomedical signal which is basically an electrical signal generated during the muscular activation. EMG signal can be measured by placing EMG sensors on the skin surface. The location of sensors depends on the muscle of interest under study.

Surface EMG and accelerometer sensor-based techniques are of growing these days as a diagnostic tool because of simplicity in operation, less expensive compared to imaging methods, and noninvasiveness. Since the signals from these sensors contain motor movement information, hence the sensors are used in the detection of frequency and activity of muscles [6]. The advantage of using EMG sensors for tremor detection is that the tremor frequency (~3-12 Hz) is within the range of EMG sensors [7]. But there is a concern about EMG signals get corrupted from multiplicative noise [8]. However, researchers developed algorithms to overcome this problem for getting the required signal [9-11]. Several techniques are available for the assessment of tremor to diagnose hand tremor, which is an early sign of PD [12-16]. Most of these techniques are based on qualitative analysis without considering the muscle activation signals. However, electromyography and accelerometry techniques provide objective measurement and analysis of tremor frequency [17,18].

## II. Methodology

This section is divided into two parts. The first part contains details of the instrument used in this study and in the second part, the experimental procedure for tremor data acquisition. Instrument

DELSYS Trigno wireless EMG instrument (Trigno Wireless System, Delsys Inc., USA) was used in our study for recording the selected muscle activity during a task. The myoelectric instrument includes a base station that interfaces 8 channels facilitating data transmission between the base station and the sensors wireless. One of 8 sensors and the base station is shown in Fig. 4. Each sensor comprises a surface EMG electrode and a tri-axial accelerometer. The system comprises a base station, 8 sensors, high-speed USB communication port, rechargeable battery, foldable antenna for data communication with each sensor, and software for data acquisition and analysis. The system is a high-performance device that can detect the sensors up to 40 m distance. It has both WiFi and Bluetooth capabilities and the signal quality are excellent, reliable, and consistent. The system is best suited for real-time EMG data acquisition and analysis purposes; and is recommended for research, medical studies, and OEM applications.

The system has a feature to stream the data to its acquisition and analysis software. EMG sensor electrodes are lightweight and small in size which can be placed over the surface of the skin and their performance is guaranteed up to 40 m long distance. Inbuilt batteries can last until 6 to 8 hours and they can sample the EMG data at 2000 Hz and accelerometer data sampling at 148.1 Hz with 16-bit resolution. Green color LED light on sensors indicates that the battery is full and ready to acquire the data. If the LED turns orange color, then the sensor needs to be changed from its base station. The design feature of providing the charging circuit within the base station enables the electrode isolated from the power supply. An arrow mark on the sensors indicates that they are required to be placed along the muscle direction in the body part. The wireless EMG sensors eliminate electrical wires between electrodes and the system which makes the data free from possible motion artifacts. Because of these advantages, Delsys Trigno Wireless EMG system is more suitable in the study as wearable body sensors.

## III. Experimental Procedure

For evaluating tremors in the hand, we acquired the data from the EMG instrument and analyzed it to get the results.

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Recording of signals was conducted from fifteen normal voluntary male adults. They were asked to relax their hands before the beginning of the tests. Their consent was asked and explained about the testing procedure. After they convinced and agreed, then they were given a small demo. In the test, they need to draw spiral drawings on white plain papers by a ballpoint pen. From each subject, two separate spiral drawings were asked; one without any tremor in the hand and another with tremor hand induced by the simulator. Below Table 4.1 shows a summary of the volunteer's information.

Table 4.1: Summary of Volunteer's information

| Sex | Age | Weight | Status of health |
|---|---|---|---|
| 15 Male | 22 ± 2 years | 60 ± 4 Kgs. | Healthy, right-hand users |

Two EMG electrodes were selected for the data collection. Each electrode can record EMG signal and accelerometer signals from their location. Each electrode has four silver bars on the bottom through which the signal flows. Fully charged sensors were affixed with double-sided specialized adhesive stickers which hold them with the skin and provided good contact between electrodes and the skin.

Two sensors were fixed on the hand of each subject. During the writing process, it has been noticed that Abductor Pollicis Brevis (Figure 5a and Brachioradialis (Figure 5b) are two muscles of the arm and hand are exerting force on writing pen [19]. Therefore, these two muscle positions were selected for fixing the sensors.

The two sensors were fixed on selected locations of the right-hand. They are positioned on the hand such that arrows marked over sensors were along the muscle direction. With the help of specialized adhesive stickers provided with the Trigno Wireless equipment, each sensor was firmly fixed. Before displacing the sensors from the base station, the status of the power charged was ensured fully. During the commencement of data recording, the LED's were switched on from a tiny press button switch provided on the sensor. Figure 6 shows the placement of two sensors on the right hand of a subject under test.

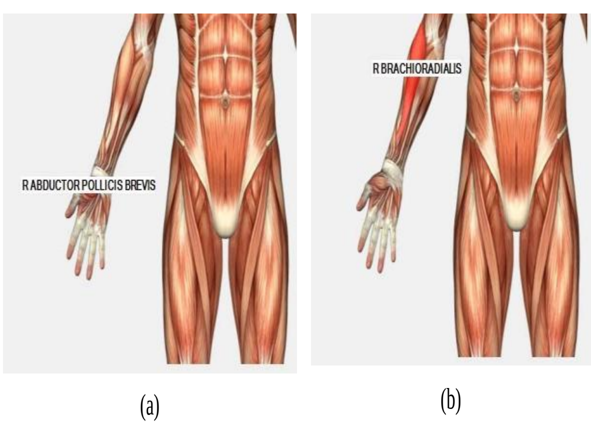


Figure 5 Anterior view two right-hand muscles for placing surface EMG sensors. (a) Abductor Pollicis Brevis, (b) Brachioradialis.

EMG and accelerometer signals from the sensors were stored in a computer for further analysis. EMG signal is complicated in nature because the myoelectric signal is controlled by the complex nervous system, also depends on anatomical and physiological features of the muscle. For a thorough analysis of such complicated signals, complete knowledge about signal conditioning and processing algorithms are essential. The main reason behind the accurate analysis of the signals is that these signals are used for clinical diagnosis and motor functioning applications. Recent developments in signal processing and mathematical modeling are further improving the signal quality [20-25]. Many of their works include advanced methods such as wavelet transform, ICA (independent component analysis), PCA, NN, and statistical methods.

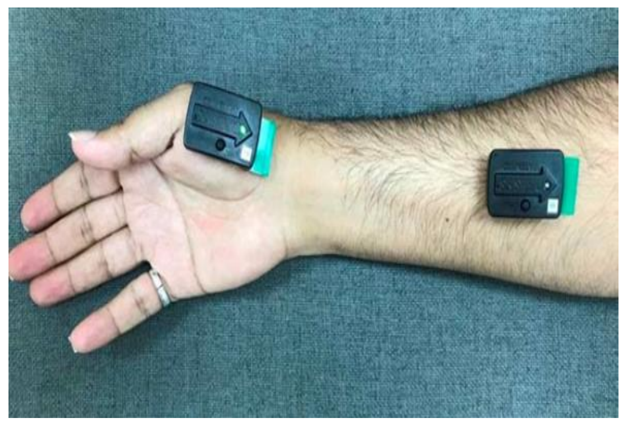

Figure 6 Placement of two EMG sensors on the right hand of a volunteer.

In the Fig. 7, it can be seen that a volunteer is performing a writing task while the sensors are fixed on his hand and tremor data is acquiring, which can be seen on the computer monitor (Fig. 8).

Figure 7 Experimental set up to record EMG and accelerometer signals from muscles during the writing task.

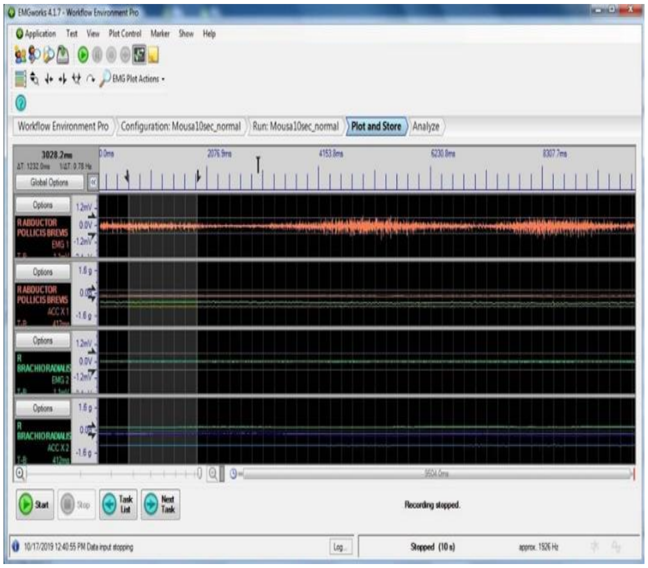

Figure 8 Snapshot of sensor's data displayed on the computer monitor.

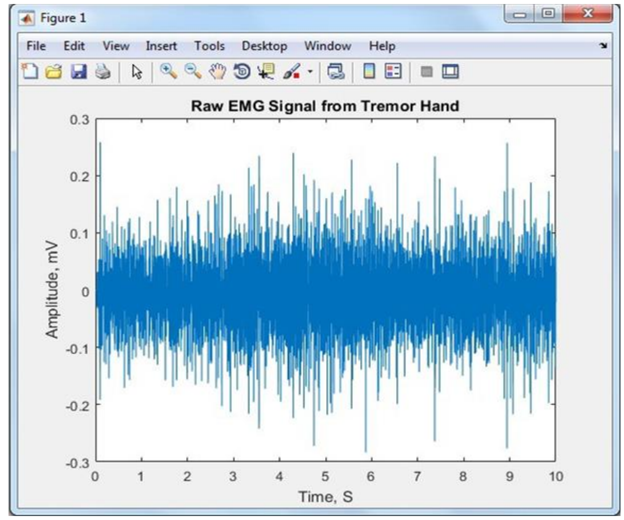


Figure 9 Raw EMG signal acquired for 10 seconds during spiral drawing from tremor hand.

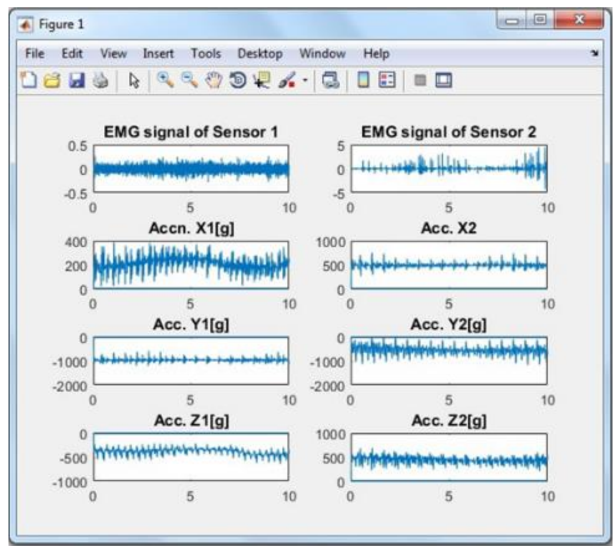


Figure10 EMG and Accelerometer signals from the two sensors fixed on the tremor hand of a person.

EMG signal is stochastic containing amplitudes of usable energy and electrical noise. The acquired signal was filtered for usable energy in the range 0-500 Hz of frequency. Electric noise was filtered out and the dominant energy in the range of 50- 150 Hz frequency was detected. Processing and analysis of the data were done with Delsys software and MATLAB platform offline. Fig. 9 shows the plot of the EMG signal acquired for ten seconds from Abductor Pollicis Bravis muscle on the right hand of the volunteer. The signal needs to be processed and analyzed. The purpose of analyzing the signals in this work is to assess the maximum useful energy localization in frequency domain during the task. Frequency domain methods are usually implemented on biomedical signals for spectral analysis applications. We applied Fourier transform on the signals and estimated power spectral densities (PSD) of each signal. FFT of the signal gives the spectrum density of the time domain signal. PSD is basically a frequency response of the signal which gives average power distribution over a range of frequency. In other words, the PSD of the signal describes the power that existed in the signal as a function of frequency. We performed the spectral analysis in the frequency domain to calculate the PSD.

## IV. Results and Discussion

Fig. 10 shows EMG and accelerometer sensor signals acquired from tremor hand. Plots in the first column show EMG signal and accelerometer signals in three axes (x, y, and z) acquired simultaneously from Sensor 1 which was fixed over Right Abductor Pollicis Bravis muscle. The similar plots from Sensor 2 that was placed over Right Brachioradialis muscle, shown in the second column. It shows that the data from two sensors are distinctively different, indicating that the muscle forces and tri-axis acceleration are mutually responding to each other due to the movement of the wrist and thumb. For a better interpretation of the results, the signals were plotted in the same figure (Fig. 11) so that the comparison of amplitudes will be much clear.

It is not possible to understand clearly about the shaking of the hand. Therefore, we performed a spectral analysis of the signals to get more information from the data. Aiming at this requirement, power spectral density (PSD) was calculated for each signal. Figure12 shows a PSD curve for one group of data. From this, it is now clear that the dominant energy is accumulated at 7.5 Hz frequency. This value of frequency was produced by the hand tremor simulator. As the tremor frequency range is from 3 Hz to 12 Hz, the frequency value obtained here is within that range. Thus, the experimental methodology of detecting tremor frequency which is useful in the diagnosis of hand tremors is achieved by employing EMG sensors. This approach is simple, easy to operate and arrive at an important conclusion about the probable Parkinsonism in people. Further, this protocol can be clinically tested on symptomatic PD patients.

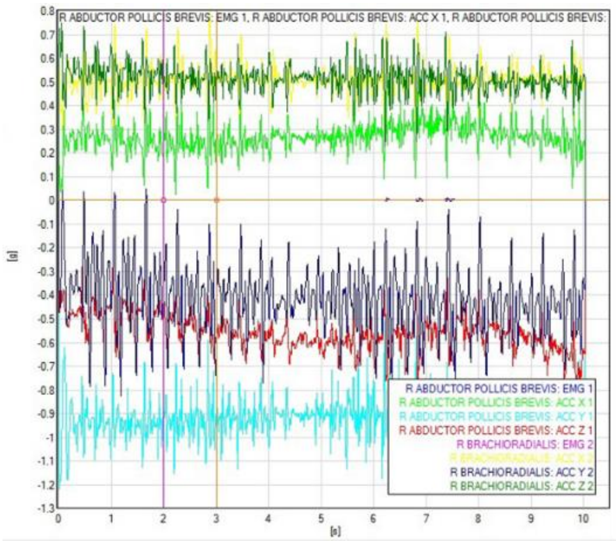


Figure 11 Preprocessed signals obtained from the hand muscles (Right Abductor Pollicis Bravis and Right Brachioradialis).

## CONCLUSION

This is an experimental procedure in which the EMG and accelerometer signals were acquired from the skeletal muscles of the hand. The data were acquired during the spiral curve drawing task. Then the signals were analyzed in the frequency domain to assess tremor frequency in the hand. Since the signals were taken from the underlying muscles of the skin, the results are relatively accurate than indirect methods of hand tremor assessment.

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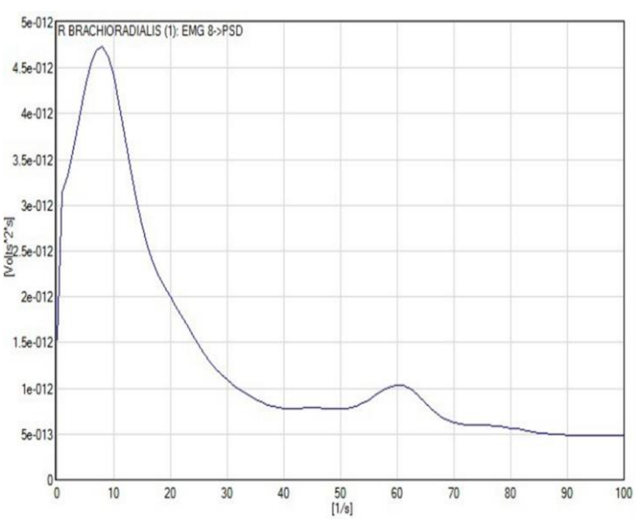


Figure 12 Spectral Analysis of EMG Signal. The power spectral density indicates the dominant frequency at 7.5 Hz.

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