Development of a Standalone Application to Measure Crosstalk in MMG Signals from Forearm Muscles during Wrist Postures

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***Abstract*— Mechanomyography (MMG) signals can be used to study and analyze skeletal muscles. It retains its potential application in various fields including athletics, sports, medicine and prosthetic control. MMG signals do exhibit crosstalk from adjacent muscles. The measurement of crosstalk in MMG signals could be beneficial for the study of muscle mechanics. Hence, this research contributes to the development of a standalone application (APP) to measure crosstalk in MMG signals coming from human forearm muscles during various wrist postures. The application has been developed on National Instruments LabVIEW software version 14.0. Peak cross correlations have been used as a measure of crosstalk between neighboring muscles. The results produced by APP while measuring crosstalk in MMG signals are very close to literature. Hence the results for APP have been validated by previous studies. The APP can be used for both forms of MMG data either stored in the form of tdms files or real-time signals. MMG signals are acquired, displayed, processed and finally used for measurement of crosstalk. All the steps are done automatically in the APP. Hence APP cannot only save time to measure crosstalk through other tedious methods but it also provides a source of MMG data validation in a real-time environment.**

***Index Terms*— Application development; Crosstalk; Forearm muscles; Mechanomyography.**

I. INTRODUCTION

Mechanomyography (MMG) is a non-invasive tool for recording of the low frequency lateral oscillations in active skeletal muscle fibres [1]. These oscillations reflect the mechanical counterpart of motor unit activity measured by electromyography (EMG) [2]. MMG monitors the dimensional changes in muscles produced during muscle contractions [3]. MMG advocates well for its reliability, performance and ease in application to other presently used techniques. There are different types of sensors available to measure the dimensional changes in muscles including accelerometers [4], piezoelectric contact sensors [5], condenser microphone [6] and laser displacement sensors [7]. Although MMG is a useful technique to assess and study muscle function and it offers potential benefit over other tools for same application but MMG possess some drawbacks. As MMG is at its infant stage of development so it needs to deal with the limitations offered by the technique itself. MMG collects mechanical signal from vibrations produced by muscles and there are chances of the signal to be contaminated. The contamination of MMG signal by the signals coming from nearby muscles is known as crosstalk. MMG exhibit crosstalk in signal inherently due to the mechanical nature of signal coming directly from the muscle. Crosstalk has been dealt with in detail in the studies related to a contemporary tool called EMG but this phenomenon needs to be addressed in depth in MMG. Crosstalk in MMG signals got a fewer record including leg muscles [8, 9] and forearm muscles[10-12]. So, there is large room to work in this area to have more benefit from clinical applications of MMG.

$$R_{x,y}(\tau) = \frac{1}{a \times b \times \omega(\tau)} \sum_{n=0}^{N-1} Xt(n)Yt(n+\tau);\ 1 - N < \tau > M \qquad (1)$$

where $a = \sqrt{\sum_{n=0}^{N-1} Xt^2(n)}$, $b = \sqrt{\sum_{n=0}^{M-1} Yt^2(n)}$ and ω is the weighting factor, M and N are the lengths of X_t and Y_t, respectively, s represents the time lag between the signals. The peak cross correlation coefficients ($R_{x,y}$) are used as a correlation function to quantify crosstalk.

In APP, the user just needs to select the data file for at least two muscles and he can not only view the original signal along with signal after processing but a numeric value for cross correlation coefficient on the user interface of APP. The peak cross correlation coefficient can be further squared to get percentage common signal or percentage crosstalk. Hence the value for crosstalk appearing on APP will always be less than 1. The APP has been validated by 80 samples collected from 20 different subjects. The results are in close proximity to the results obtained in [10], for forearm muscles. Hence the validity of APP has been justified by literature. The APP can serve as a time saving tool while doing experiments using MMG set up. It can give a highly efficient estimate of MMG signal contamination. So, the development of this standalone application which does not need any specific software installation requirements on the computer to get use of it, can pave a path for ease and efficacy in muscle study via MMG.

II. FOREARM MUSCLES AND WRIST POSTURES

Forearm muscles are important for their participation in different activities produced through hand-arm coordination like wrist extension, wrist flexion, radial deviation, ulnar deviation, supination and pronation. More than ten muscles are involved in hand and wrist extension. These muscles are smaller in size, near each other and have a small area on muscle on which sensor is placed. Due to all these factors related to the physiology of forearm muscles, the signal coming from these muscles via MMG are prone to be contaminated. Crosstalk in EMG and MMG signals from forearm muscles has been observed [10, 16]. In this research, four different wrist postures have been studied for crosstalk quantification. Three muscles are under observation for this research namely extensor digitorum, extensor carpi ulnaris, flexor carpi ulnaris. The wrist postures are shown in figure1. The location of three muscles can be seen in figure 2. The values of cross correlation coefficient $R_{(x,y)}$ are ranged between .025 and 0.67 for 80 different trials using the APP. These results are very much close to [10]. Forearm muscles show higher values of crosstalk due to their physiology. A large range of values of crosstalk has been measured which is also validated by [9].

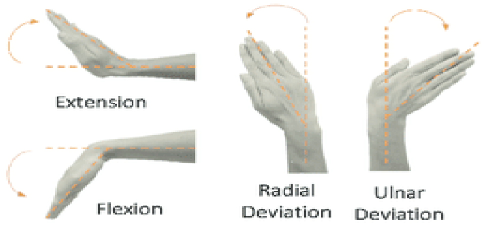

Figure 1: Different Wrist postures

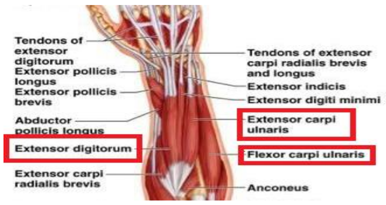

Figure 2: Location of forearm muscles

III. Development Of Standalone Application

This standalone application for the measurement of crosstalk between muscles has been developed in LabVIEW systems engineering software environment by National Instruments. The flow chart for APP has been given in Figure 3. Flow chart elaborates the work flow of the APP. The APP works for both the options of real-time data and stored data in the form of a file. The file could be with both the extensions either .exe or .tdms. Both the file formats need to be converted into text tab delimited file types. The user simply needs to select one of the two options between real-time data and stored data files. The graphical user interface of APP is shown in figure 4 while a block diagram depicting architecture of APP is shown in figure 5.

For measurement of crosstalk in MMG signals from live data coming from forearm muscles the establishment of experiment with the protocol is required. Three accelerometers (ADXL 335, Analog Devices, USA with frequency response 0.5-500 Hz and sensitivity of 330mV/g) were employed to measure MMG signals coming from three forearm muscles namely Extensor digitorum, extensor carpi ulnaris and flexor carpi ulnaris. The sensor was placed on the belly of muscle as this region gets maximum of mechanical vibrations. The output of each of the sensor was connected to the data acquisition unit (NI cDAQ 9191 with NI 9205 module, National Instruments, Austin, TX, USA). It recorded the data at a rate of 1000 samples /s and stored it in an array destined to a tdms file in the computer. Real time data also undergoes same signal processing and middle sample selection as in case of stored data. The user simply selects the option for live data and then choose three paths which are the physical channels coming from data acquisition system. These channels are getting signals direct from forearm muscles. The APP displays the output for all the three physical channels in three different waveform graphs. The APP measures crosstalk in the form of cross correlation coefficient and display three numeric values on the graphic user interface of APP. For each pair of muscle, we get a single value of crosstalk.

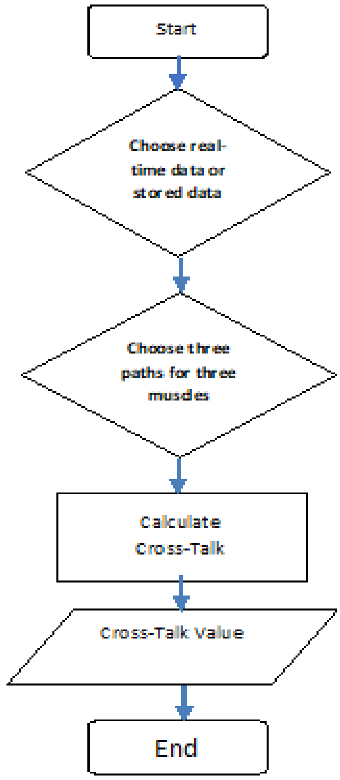

Figure 3: Flow chart for the development of APP

If stored data option is chosen, the user selects the corresponding tab and three file paths for three distinct muscles as shown in Figure 4. The data collected from forearm muscles have already saved in the tdms file format. The APP automatically selects a range of 5-100 Hz frequency of signals through band-pass filtering. The APP selects the middle 2000 samples, and neglects the initial and last samples. The reason for selecting the middle portion is that at this point, muscles have maximum natural activity. This is just to avoid signal selected muscle. These waveforms show data in the units of acceleration converted from units of voltage. The APP measures crosstalk between all the three muscles considering them in pairs. Hence, three crosstalk values are displayed for three muscle pairs.

The reason to choose forearm muscles for APP validation is evident as there is a bunch of literature on crosstalk measurement in forearm muscles via EMG. So, we have records to support the results produced by APP. Also, crosstalk has been studied for large muscles in the leg. So, there is a need to analyze this phenomenon in smaller muscles. So, forearm muscles are an excellent choice to deal with. The mean crosstalk values for all the three muscle pairs and four wrist postures calculated from the APP are very close to [10] in results.

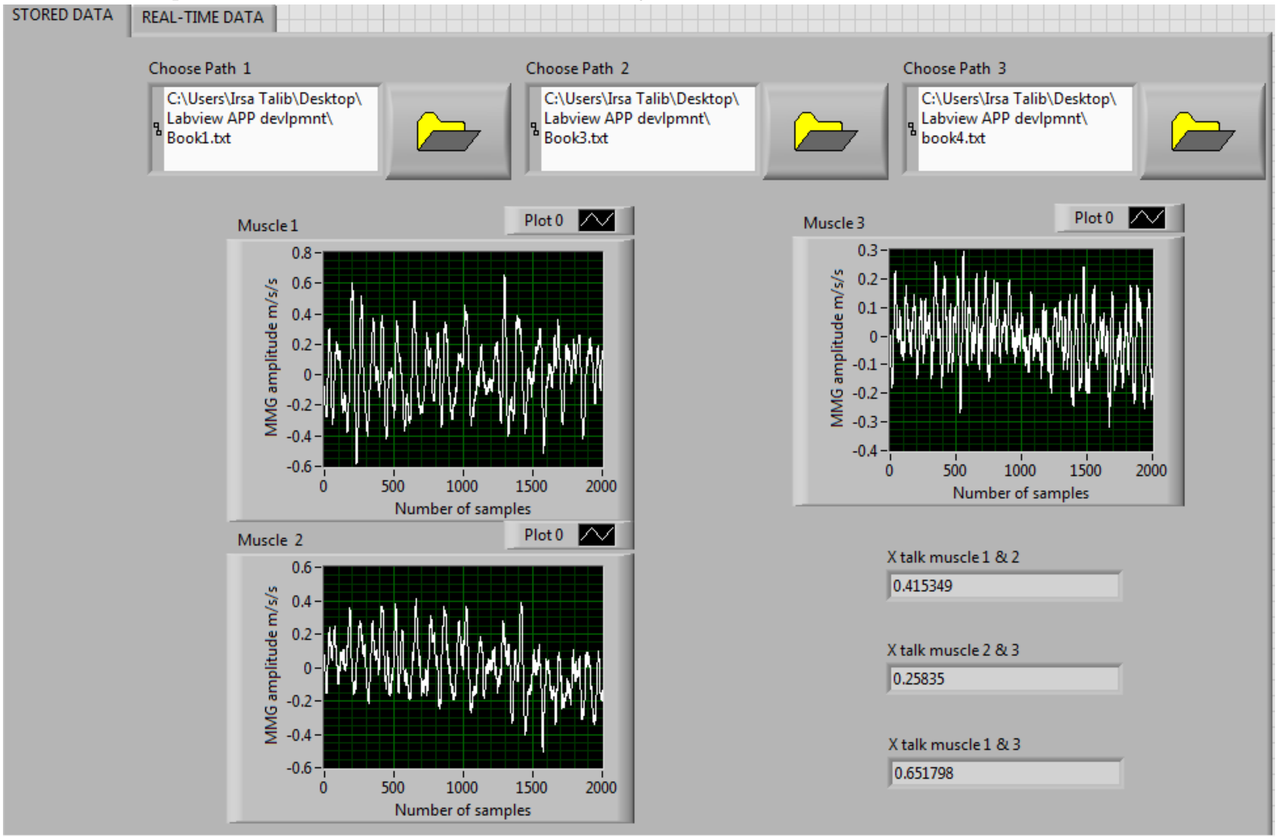

Figure 4: Graphic user interface for APP

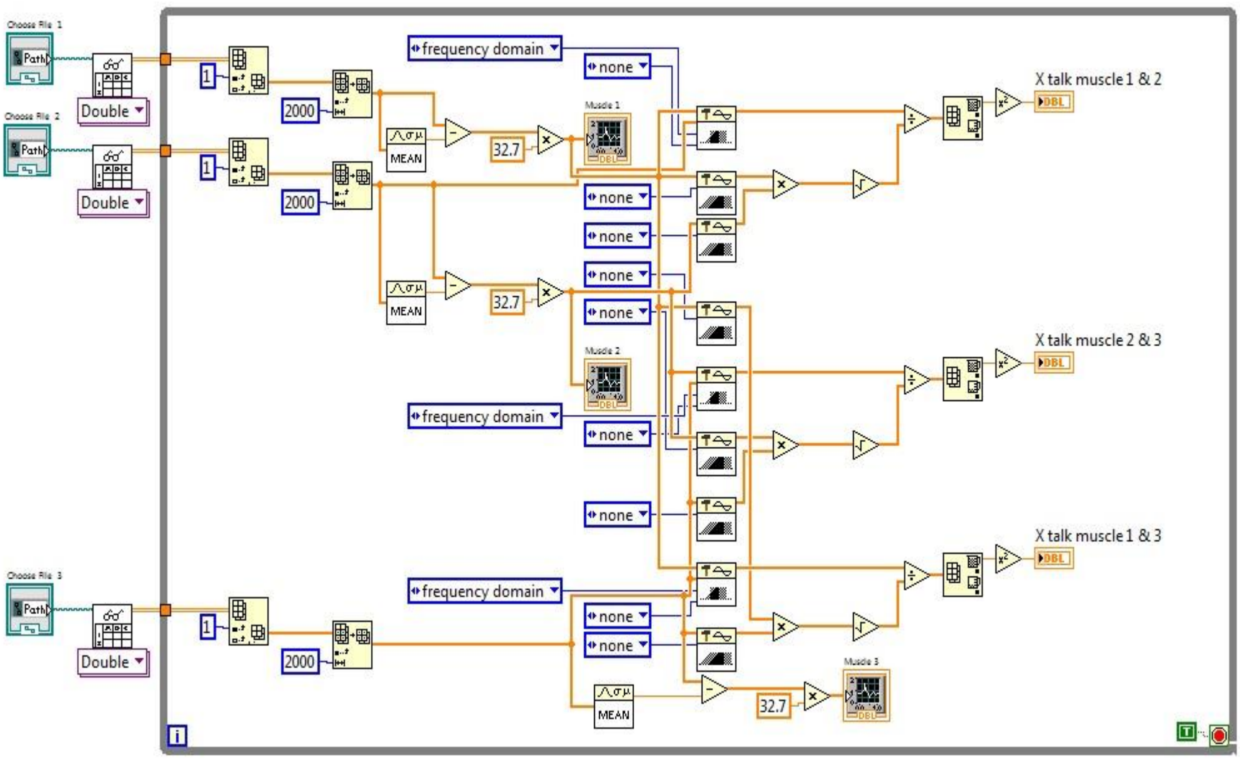

Figure 5: Block diagram showing the construction of APP

IV. Results and Discussion

The results of APP were tested on 80 samples coming from 20 different subjects taken from the three above mentioned forearm muscles. For each of the subject there are four wrist postures so, a total of 80 samples were gathered. The value of crosstalk ranged from 0.025 to 0.67. This range of values is verified by literature. The presence of crosstalk in MMG signals coming from forearm muscles may be attributed to muscle physiology specifically size of muscles, closer proximity to each other and relatively small area on muscle for sensor placement.

Crosstalk between extensor muscles is higher in comparison to crosstalk between extensor and flexor muscles. This is since muscles belonging to same activity group contain more content of skin, bone and tissues. Skin and tissues are low pass filters, hence the amplitude of MMG signal is higher for extensor muscles. So, crosstalk between extensor muscle activity group is also higher. Type of muscle contraction effects MMG signal, hence static contractions exhibit a wide range of crosstalk values between forearm muscles as observed by APP [17].

The crosstalk values between extensor carpi ulnaris and flexor carpi ulnaris for radial deviation give a difference to other three postures. This trend was observed for most of the samples. It is since this pair of muscle does not participate in radial deviation so there is a difference in crosstalk observation. All the results are close to the values observed in previous studies.

V. CONLCUSION

The simple graphic user interface makes the use of APP easy even for a novice. The dual-purpose APP is capable of crosstalk measurement in both the environments including real-time and stored data format. It gives a provision to measure crosstalk in muscles on the spot while experimenting. Finally, the results for the APP are validated by [12] and [9]. This APP can be extended for its application on muscles other than the forearm muscles. It can save time and provide verified results as tested through experiment and supported by previous studies.

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