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Feature Extraction Methods for Analysis of SEMG Signals

Devika K and Prof. Sidharth N
Department of Electronics and Communication Engineering
NSS College of Engineering, Palakkad, Kerala

Abstract: *Electromyography (EMG) is used to measure and keep information of the electrical activity that produced by muscles during contract and relax. The electrical activity is detected with the help of EMG electrodes. Surface electromyography (sEMG) is one type of bioelectrical signal produced by the human body. sEMG contains meaningful information associated with muscle activity and has numerous applications in motor control and neuromuscular physiology. sEMG signals can be used to identify the movement intention and evaluate the function status of muscles. sEMG is also applied in virtual reality with the advances of technology development. During sEMG recording, there are some recognized noises and motion artifact which will affect sEMG signal. Hence, several of signal processing had been implemented to remove the noises and acquired the important signals which contain useful information. sEMG feature extraction is highlighted part in signal processing which extract features in sEMG signal. In this paper, several of sEMG feature extraction that applied any of three main domains which are time domain (TD), frequency domain (FD) and time-frequency domain (TFD) had been analyzed and studied to determine the good feature extraction method.*

Keywords: Electromyography

I. INTRODUCTION

Electromyography (EMG) is collective electrical signal acquired from skeletal muscle and includes the signals which have contains useful information from muscle contraction. Besides that, EMG also is a technique to measures and keeps information of the electrical signal produced from a small electrical currents during muscle contraction and also known as myoelectric signal. The myoelectric signal that generated can be detected by using EMG electrodes. Generally, EMG electrodes can divide by two main types which are surface skin electrodes and inserted muscle electrodes. In intramuscular emg electrodes is in the form of needle which is injected into the muscle and it follows the muscle movement with its contraction and relaxation. This method is very painful. In surface EMG electrodes are placed on the skin. They contain a conductive gel that is used to pickup the electrical signals from nervous system to muscle. So, SEMG is more preffered for analysis. It investigate muscle activation and fatigue. It is easy to implement and more convenient to use especially in engineering application and researcher.

The surface electromyography (sEMG) signal is a complex interference pattern of the electrical activity during the muscle contraction. It is closely related to muscle activity and exercise status. Its amplitude is generally 0.01mV to 10mV and its main energy is concentrated between 0Hz and 500Hz frequency band. Detection of sEMG signals is a non-invasive method, which is of great importance in clinical diagnosis, rehabilitation medicine and intelligent prosthetic control. In recent years, EMG has been used in the gesture recognition of sign language, game control and wearable device. Basically, surface electrodes can be divided into two types which mainly used that are gelled electrodes and dry electrodes. A gelled electrode is containing substance interface between electrodes and skin that known as electrolytic substance. Substances of silver-silver chloride (Ag-AgCI) is the suitable combination of metallic part and silver chloride (AgCI) layer which lets the current acquired from the muscle to move freely through the electrolyte and electrode. Before placed the gelled EMG electrodes on the human skin which are the skin must be shaving off any hair and exfoliating and finally cleaning by 70% Isopropyl Alcohol. That will help to reduce unnecessary of noise and to acquire the best signal while EMG signal recording. On the other hand, dry EMG electrodes will measure the EMG signals by directly with human skin without any chemical interface such as electrolytic gel. Commonly, dry electrodes along with garments conductive yams that consisted of metal coated filaments provide a comfort wearing when stitching into it.

Once the sEMG signals are acquired, the next step involves the signal processing. The sEMG signal can be easily contaminated by other types of signals; therefore it is important to reduce the noise mixed in the sEMG signal. In addition, how to extract useful feature information from the original one-dimensional time series sEMG signal is a critical component in sEMG data analysis. In this paper, sEMG denoising methods are summarized. Also, review representative algorithms for feature extraction methods and classification of sEMG signals.

II. ELECTROMYOGRAPHY PREPROCESSING

When dealing with EMG signal, noise removal is a very important factor to be taken into consideration. This is due to the sensitive nature of EMG signal itself that different types of noises or artifacts unavoidably contaminate it. These noises are caused by various sources originates from either the skin-electrode interface, hardware that intensifies the signal, or other external sources. Therefore, before proceeding with the analysis and classification of EMG signal, a preprocessing is usually introduced to remove these noises. Hence, it is important to know sources of noises that recognized affect sEMG signal and this can be categorized into four types that are inherent noise, ambient noise, movement artifact, cross talk and internal noise.

1. Inherent Noise: Inherent noise is obtained from electronics equipment which is each electronic equipment produces noise.
2. Ambient Noise: Ambient noise is the source of noise where generated by electromagnetic radiation such as television transmission, electrical-power wires and radio
3. Movement Artifact: The movement of the wire used that connect electrodes with amplifier circuit.
4. Cross talk:Unwanted signal that generated from active muscle that near to desired skeletal muscle (target muscle).
5. Internal noise: It most related with human body structure which involved the depth and location of the muscle fiber between surface electrodes and active muscle, the amount of excess body fat that will increase the distance or separation between surface electrodes and active muscle fiber.

In order to get the actual raw EMG signal, several approaches need to be done in analyzing the EMG signal. Thus, important to know the proper feature that can be extracting from the EMG signal. The wrong feature extraction used might affect the raw EMG signal.

sEMG denoising: sEMG denoising involves two categories: hardware denoising and software denoising. The hardware denoising method improves the signal-to-noise ratio by improving the performance of the acquisition instrument, such as using a spatial filter. The software denoising method is widely used in sEMG signals, including filters and wavelet transforms.The wavelet analysis theory, as an extension to traditional Fourier transform, has been increasingly explored in signal denoising. The wavelet coefficients have different characteristics at each scale of noise and signal. So the basic idea is to remove the wavelet components generated by noise at each scale. The retained wavelet coefficients are basically the components of the original signal. Then, the wavelet inverse transform is used to reconstruct the original signal. There are three methods used for filtering, including modular maximal reconstruction filtering, spatial correlation filtering, and threshold filtering.

III. ELECTROMYOGRAPHY PROCESSING

Biosignal processing is a critical part in biomedical engineering in order to classify the frequency content of a signal. These signals include EMG, electrocardiography (ECG), and electroencephalography (EEG). Most of these biosignals are non-stationary signals due to its time-varying characteristics. The problem of this non-stationary signal is the process of assuming it to be stationary over short-time intervals, where stationary analysis techniques are used. However, this assumption is not always suitable, and further methods for non-stationary processes are needed.

There are several techniques to process the non-stationary signal specifically the EMG signal and these include parametric and non-parametric approaches. The differences between these two approaches are mainly due to the parameters involved. Since most of the signals encounters are unknown signals without known parameters, the

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development of non-parametric approach, which involves a variety of transforms, is actively researched compared to the parametric approach that requires the modelling of the non-stationary process.

3.1 Parametric Approach

In the field of EMG processing, one type of parametric approach that has been explored is based on the time-varying linear predictive models. This includes time-varying autoregressive (TVAR) model where its parameters vary with time. The time-varying spectrum in TVAR is estimated from the time-varying model parameters and the nonstationary signal's instantaneous frequency (IF)can be extracted. IF represents the spectral peak location of the EMG signal as it varies with time. Computation of the mean frequency is taken as the average of the IF estimation based on the cascaded model in each interval. On compairing TVAR with short-time fourier transform it concludes that even though both TVAR and STFT have produced similar decreasing muscle fatigue patterns from the MNF, TVAR has achieved a better performance with slope and interception of the linear regression line is closer.

Another parametric approach that has been used is the time-varying autoregressive moving average (TVARMA). AR models are more favorable than ARMA because of estimation of AR models is moderately basic since they are represented by an arrangement of direct mathematical statements. AR models are predominant in displaying the low recurrence sEMG segment and fluctuation of the AR model estimation on shorter fragments is lower than for ARMA models.

3.2 Nonparametric Approach

Another EMG processing method is the nonparametric approaches, which include STFT, spectrogram, wavelet transform. These approaches appear to be more favorable since the fatigues indices can be obtained directly from the EMG signal without knowing its parameters. The analysis of the EMG signal based on the nonparametric approaches can be further divided into three types of distribution techniques: time domain, frequency domain and time-frequency domain.

A. Time Domain Feature Extraction

Time domain presents the behaviour of the signal in time. Time domain features have been extensively used in biological system, engineering applications and researches. Most common method used for signal classification is time domain method due to its reduction in complexity that related with the feature extraction, low noise in environment, and easy to implementation especially the features of the raw EMG data is calculated in time series. Mean Absolute Value (MAV), Root Mean Square (RMS), Zero Crossings (ZC), Slope Sign Changes (SSC), and Waveform Length (WL) are the simple time domain features. Additional methods had been utilized for time domain feature extraction are including Integrated EMG (IEM), Modified Mean Absolute Value 1 (MMAV1), Modified Mean Absolute Value 2 (MMAV2), Simple Square Integral (SSI), Variance of EMG (VAR), Root Mean Square (RMS), Willison Amplitude (WAMP), and Histogram of EMG (HEMG).

B. Frequency Domain Feature Extraction

Frequency domain is one of the methods used to analyse the signal data obtained in frequency. In frequency domain analysis used transformation concept which it will convert a time domain function that obtained from raw EMG data to a frequency domain function. In additional, power spectral density (PSD) is a main analysis in frequency domain where its function is to measure the present of power signal in frequency domain. There are eleven frequency domain features had been carried out which are mean frequency (MNF), median frequency (MDF), peak frequency (PKF), mean power (MNP), total power (TTP), the 1st, 2nd, and 3rd spectral moments that known as (SM1), (SM2), and (SM3), frequency ratio (FR), power spectrum ratio (PSR), variance of central frequency (VCF). In many studies of fatigue muscle, frequency domain features are usually used to extract information from a signal. To date, there are more than 20 fatigue indices in the frequency domain, where two of the widely used parameters are the mean frequency (MNF) and median frequency (MDF).The EMG signal should undergo Fourier transform in order to represent the signal in frequency domain. However, the fluctuations of the EMG frequency component due to the adjustments in the muscle force, length and contraction speed throughout time, have caused challenges in the usage of FFT and other traditional processing methods. The fundamental confinement of a FFT is that it cannot give simultaneous time and frequency localization. Therefore, investigation of the EMG signal in dynamic contraction (i.e., repetitive lifting) utilizing these methods may not be successful since it requires the signal to be stationary.EMG features based on frequency domain are not suitable in classification of the EMG signal is due to classification accuracy of several frequency domain features are found approximation to the time domain features.

C. Time-Frequency Domain Feature Extraction

Various signals analysis in many applications including biomedicine, multimedia, radar and industry preferred to deal with this time-frequency signal analysis method which can provide signal information in both time domain and frequency domain. Other than that, type of signal provided is a nonstationary signal where present of frequency components vary with time. Therefore, this method is more suitable to implement in sEMG signal analysis which the type of sEMG signal is also is a non-stationary signal that contain various frequency components. A recent work had been exploited that the short-time Fourier Transform (STFT)-ranking feature was determined more satisfactory performance rather than other features tested which including frequency domain features and time domain features for motion pattern recognition in their research.

Time-frequency representation (TFR) of a signal maps a one-dimensional signal of time into a two-dimensional of time and frequency. In analyzing, modifying, and synthesizing nonstationary signals, TFR are widely used since both representation of time and frequency are taken into account, thus leading to higher accuracy.

In general, TFDs consist of linear TFDs and bilinear (quadratic) TFDs. The most basic form of TFD technique is the short-time Fourier transform (STFT). STFT is one of the linear TFDs that have been used to analyze EMG signals along with spectrogram, wavelet transform, S-transform, and so forth. Examples of the bilinear TFDs include the Wigner-Ville distribution (WVD) and Choi-William distribution (CWD).

D. Short-time Fourier Transform

STFT is the oldest analysis technique in area of time frequency analysis that generated by transformation of a longer time signal which proposed to break into a shorter segment of same span and followed by applying the Fourier Transform to each shorter segment. Hence, the time interval for this process is shorter compared to be entire signal length. The function of the STFT method analysis is used in various signal representation which to determine phase content and frequency of a signal obtained as it changes along time.

The choice of the window function in STFT is critical in order to get accurate results. The shape of the window can be either rectangular, Gaussian, or elliptic, depending on the shape of the signal.

$$\mathrm{STFT}_x(t,w) = \int_{-\infty}^{\infty} x(\tau)\, w(\tau - t)\, e^{-2\pi f \tau} d\tau$$

Spectrogram: The squared magnitude of the STFT is called spectrogram. Spectrogram can be used to obtain the power distribution and energy distribution of the signal along the frequency direction at a given time.For both STFT and spectrogram, there is a compromise between the time-based and frequency-based perspective of a signal. Both time and frequency are represented in limited precision, where precision is controlled by the span of the window, and the size of the window chosen will be the same for all frequencies.

$$S_x(t,f) = \left| \int_{-\infty}^{\infty} x(\tau)\, w(\tau - t)\, e^{-2\pi f \tau} \right|^2 d\tau$$

E. Wavelet Transform

Recently, wavelet is best method has been used for the signal analysis in biomedical, engineering and researcher application. A wavelet is a waveform of effectively limited duration that has an average value of zero. Some of its properties are short-time localized waves with zero integral value, the possibility of time shifting, and flexibility.The signal acquired in fourier transform only will divided the signal into a series of sine and cosine signal of different frequencies while wavelet transform (WT) is more complicated method that uses basis function that called wavelets, mother wavelet and analysing wavelets. Many researchers attempt to use a WT in signal analysing for acquired best features that represents raw EMG signal. WT is an effective measurable tool to analyse a highly fluctuated signal like EMG signal where WT had good performance in visualization of neuropathy and myopathy activities compared to STFT.

$$\mathrm{CWT}_x = \int_{-\infty}^{\infty} x(\tau) \frac{1}{\sqrt{|a|}} \Psi\left(\frac{\tau - t}{a}\right) d\tau$$

Wavelet transform method consists of two categories which are discrete wavelet transform (DWT) and continuous wavelet transform (CWT). CWT displays the distribution of signal amplitude and phase into two variables which are time and scale. Basically, the efficiency of the feature extraction might have disturbed by a large amount of data produced in CWT analysis. The redundancy of CWT can be solved by scale and translate in DWT method.

F. S-Transform

Another TFD technique exists is the S-transform. This technique has been widely used in diverse areas of telecommunication, power quality, geophysics, and biomedicine, due to its obvious advantages in processing nonstationary signals. n the area of EEG and ECG, despite the use of S-transform in the time-frequency analysis, this technique is also a good alternative for denoising and removal of artifacts that exist in ECG and EEG signals [94]. Even though it has been explored in the areas of EEG and ECG, there are no available researches conducted in utilizing this technique for EMG signal. S-Transformis a hybrid of two advanced signal processing techniques which are STFT and WT. Due to this, it inherits the good qualities from both techniques. It provides good resolution in both time and frequency and allows users to assess any frequency component in the time-frequency domain without the need of using any digital filter. Even though S-transform uses a variable window length to maintain a good time-frequency resolutions for all frequencies, it still retains the phase information using a Fourier kernel.

$$\mathrm{ST}_x(t,f) = \int_{-\infty}^{\infty} x(\tau) \frac{|f|}{\sqrt{2\pi}} e^{-(\tau-t)^2\tau^2/2} e^{-j2\pi f\tau} d\tau$$

The development of the S-transform is led by the urge to overcome the low resolution of STFT and the absence of the phase information in CWT. Since the features had existed in the S-transform, it is sometimes viewed as a variable sliding window STFT or a phase-corrected CWT. Although S-transform has better time-frequency resolution than STFT, the resolution is still far from perfect and needs improvement. To date, there are several improved S-transform introduced by researchers such as the modified S-transform and discrete orthonormal S-transform.

IV. CONCLUSION

In the area of EMG signal currently evolves around the sensitivity, variability, and repeatability of the fatigue indices, as well as the best processing techniques with high efficiency and less computational complexity. Despite the use of traditional methods such as time distribution and frequency distribution, time-frequency distribution is found to be more superior in terms of monitoring since it enables the user to observe the progress of the signal in time and frequency.The important thing that needs to highlight in process of sEMG classification system is to choose the best feature extraction. The successful of the electromyogram classification system is most depends on the selected and extracted features quality. As mentioned earlier, sEMG signal is very sensitive and easily affected. Hence, original or the raw sEMG signal easy to lose when various noise and artifact detected among EMG signals. Researchers need to use different type of feature extraction methods to find the best feature to extract the signals.

REFERENCES

[1]. Somar Karheily, Ali Moukadem, Jean-Baptiste Courbot, Djaffar Ould Abdeslam, “sEMG Time-Frequency Features For Hand Movements Classification”,IRIMAS - Institut de Recherche en Informatique Mathématiques Automatique Signal - IRIMAS - UR 7499 (2021)

[2]. Narayan, Yogendra. "Direct comparison of SVM and LR classifier for SEMG signal classification using TFD features." Materials Today: Proceedings 45 (2021): 3543-3546

[3]. Narayan, Yogendra. "Comparative analysis of SVM and Naive Bayes classifier for the SEMG signal classification." Materials Today: Proceedings 37 (2021): 3241-3245

[4]. Vivek Ahlawat, Yogendra Narayan, and Divesh Kumar, “DWT-Based Hand Movement Identification of EMG Signals Using SVM”, Proceedings of International Conference on Communication and Artificial Intelligence,(2021) : 495-505

[5]. Somar Karheily, Ali Moukadem, Jean-Baptiste Courbot and Djaffar Ould Abdeslam, “Time-frequency Features for sEMG Signals Classification”, IRIMAS - Institut de Recherche en Informatique Mathématiques Automatique Signal - IRIMAS - UR 7499 (2021)

[6]. Tanvir Ahmed and Md. Kafiul Islam, “EMG Signal Classification for Detecting Neuromuscular Disorders”, Journal of Physics: Conference Series. Vol. 1921. No. 1. IOP Publishing, 2021

[7]. Ting Yao, Farong Gao, Qizhong Zhang and Yuliang Ma, “Multi-feature gait recognition with DNN based on sEMG signals”, Mathematical Biosciences and Engineering 18.4 (2021): 3521-3542

[8]. M.B. I. Reaz, M. S. Hussain and F. Mohd-Yasin, “Techniques of EMG signal analysis: detection, processing, classification and applications”, Biological procedures online 8.1 (2006): 11-35

[9]. Núria Massó , Ferran Rey, Dani Romero, Gabriel Gual, Lluís Costa and Ana Germán, “Surface electromyography applications in the sport”, Apunts Med Esport 45.165 (2010): 121-130

[10]. Yurong Li , Wenxuan Zhang , Qian Zhang , and Nan Zheng, “ Transfer Learning-Based Muscle Activity Decoding Scheme by Low-frequency sEMG for Wearable Low-cost Application”, IEEE Access 9 (2021): 22804-22815

[11]. Burhan, Nuradebah, and Rozaimi Ghazali. "Feature extraction of surface electromyography (sEMG) and signal processing technique in wavelet transform: A review." *2016 IEEE International Conference on Automatic Control and Intelligent Systems (I2CACIS)*. IEEE, 2016.

[12]. Shair, E. F., et al. "EMG processing based measures of fatigue assessment during manual lifting." *BioMed research international* 2017 (2017).

[13]. Wu, Jiajia, et al. "sEMG signal processing methods: a review." *Journal of Physics: Conference Series*. Vol. 1237. No. 3. IOP Publishing, 2019.

[14]. Rabbi, Mohammad Fazle, et al. ”Time and frequency domain features of EMG signal during Islamic prayer (Salat).” 2017 IEEE 13th International Colloquium on Signal Processing its Applications (CSPA). IEEE, 2017.

[15]. Azhiri, Reza Bagherian, Mohammad Esmaeili, and Mehrdad Nourani. ”Real-time emg signal classification via recurrent neural networks.” 2021 IEEE International Conference on Bioinformatics and Biomedicine (BIBM). IEEE, 2021.

[16]. Azhiri, Reza Bagherian, Mohammad Esmaeili, and Mehrdad Nourani. ”Emg-based feature extraction and classification for prosthetic hand control.” arXiv preprint arXiv:2107.00733 (2021).

[17]. Azhiri, Reza Bagherian, et al. ”Emg signal classification using reflection coefficients and extreme value machine.” 2021 IEEE Biomedical Circuits and Systems Conference (BioCAS). IEEE, 2021.

[18]. T Mahmooda, Noof, et al. ”Pattern Recognition of Composite Motions based on EMG Signal via Machine Learning.” Engineering and Technology Journal 39.2 (2021): 295- 305.

[19]. Daud, Wan Mohd Bukhari Wan, et al. ”Features extraction of electromyography signals in time domain on biceps brachii muscle.” International Journal of Modeling and Optimization 3.6 (2013): 515.

[20]. Raurale, Sumit A., John McAllister, and Jesus Mart ´ ´ınez Del Rincon. ”EMG biometric ´ systems based on different wrist-hand movements.” IEEE Access 9 (2021): 12256-12266.

[21]. Too, J., et al. ”Classification of emg signal based on time domain and frequency domain features.” International Journal of Human and Technology Interaction (IJHaTI) 1.1 (2017): 25-30.

[22]. Dubey, Rahul, et al. ”Automated diagnosis of muscle diseases from EMG signals using empirical mode decomposition based method.” Biomedical Signal Processing and Control 71 (2022): 103098.

[23]. Taghizadeh, Zahra, Saeid Rashidi, and Ahmad Shalbaf. ”Finger movements classification based on fractional fourier transform coefficients extracted from surface emg signals.” Biomedical Signal Processing and Control 68 (2021): 102573