Different Approaches for Artifact Removal in Electromyography based Silent Speech Interface

Pallavi Patil, Gunjan Gujarathi, Geeta Sonawane

Abstract **- Surface electromyography (EMG) can be used to record the active potentials of articulatory muscles while a person speaks. Electromyography signals recorded from the facial muscles can capture the movements of muscle cells; therefore allow retracing speech, even when no audible signal is produced. This paper introduces basic EMG signal, data acquisition methods, artifacts and methods for their removal. Recent research has taken some different approaches for artifact removal required for silent speech interface. Our goal is to assist the EMG signal analysis for persons who are disabled to produce functional speech using their tongue and lips, aphonic or have severe motor speech impairment. This paper reveals the different approaches for the removal of artifacts in the EMG signal.**

Index Terms **– Electromyography, articulatory muscles, artifacts.**

I. INTRODUCTION

The most natural way of communication between human beings or human being and machines is speech. It is the means of communication between machines with the advent of telephonic devices and speech based electronic devices. For classical voice based communication, it is necessary to have audible clear speech signal. But this brings disturbance for bystanders, lack of robustness in noisy environment, exclusion of speech disabled people [5]. Many people are speech disabled so it is necessary that the speech of such persons must be recognized and then conveyed. For such problems Silent Speech Interface (SSI) systems are developed which aids in enabling to speech communication to take place without the necessity of audible acoustic signal. Electromyography (EMG) refers to monitoring electric potential generated by muscle cells when the cells are neurologically or electrically activated. This is controlled by human nervous system and produced during muscle contraction. EMG signal defines the anatomical and physiological properties of muscles. EMG consists of two types: surface EMG, and intramuscular EMG. Surface EMG assesses muscle function by recording muscle activity from the surface above the muscle on the skin. Intramuscular EMG can be performed using a variety of different types of recording electrodes. The simplest approach is a monopolar needle electrode. This can be a fine wire inserted into a muscle with a surface electrode as a reference; or two fine wires inserted into muscle referenced to each other. This method recognized the speech signal without the need of any mouthed vocal effort. Nowadays, to detect EMG signals of facial movements system uses electrode arrays.

The major sources of recognition errors are different artifacts which arise from technical sources or biological sources. Independent Component Analysis (ICA) is an EMG signal processing technique, actually extracts localized sources of EMG activity.

This paper deals with basics of EMG signal, their data acquisition methods, preprocessing techniques on EMG signal which removes artifacts from the signal. Such signal can be further utilized for SSI system so that handicapped or non-handicapped speakers and where absolute silence is required can utilize the system.

II. DATA ACQUISITION

For EMG recording the multi-channel EMG amplifier EMG-USB2 is used, produced and distributed by OT Bioelettronica, Italy (http://www. otbioelettronica.it/) [5]. The EMG-USB2 amplifier allows to record and process up to 256 EMG channels, supporting a selectable gain of 100 - 10000 V/V and a recording bandwidth of 3 Hz - 4400 Hz. For line interference reduction used the integrated DRL circuit. The electrode arrays were acquired from OT Bioelettronica as well.

Electrolyte cream was applied to the EMG arrays in order to reduce the electrode/skin impedance. The two different EMG array configurations used for the experiments are shown in Fig. 1. Setup A makes use of unipolarly recorded 16 EMG channels with two EMG arrays. Each array uses a single row of 8 electrodes with 5 mm inter-electrode distance (IED). As shown in Fig. 1, Setup A shows that one array is attached to the person's cheek. This array records the major articulatory muscles. The other one is attached to the person's chin which captures signals obtained from the tongue. One reference electrode was placed on the subject's neck. For setup B, the cheek array is replaced with a larger array consisting four rows of 8 electrodes having 10 mm IED. The chin array remained in the same position as in Setup A.

Fig. 1.(a) Setup A (b) Setup B

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The Setup B gives a cleaner signal by using a bipolar configuration. This configuration measures the potential difference between two adjacent channels in a row [6]. The produced EMG signal contains different types of noise signals which are discussed in the next section.

III. ARTIFACTS IN EMG SIGNALS

The behavior of the EMG signal depends upon the internal structure of the subject, including the individual skin formation, blood flow velocity, measured skin temperatures, the tissue structure like muscle, fat, etc. and the measuring site. These attributes produce different types of noise signals that can be found within the EMG signals such as,

A) Inherent source is the first type of noise source. Electrodes with 10 × 1 mm silver/silver chloride are applied for recording purposes gives electrically more stable adequate signal-to-noise ratio. So that surface electrodes are widely used [9]. Impedance decreases with the increase in electrode size. The two parameters needs to be taken into consideration, the size of electrode should not be very large to obtain signal quality and to give low signal-to-noise ratio the high electrode impedance is required. For experiments in which statistical power is high or in which large numbers of electrodes are necessary use high electrode impedances, whereas use low electrode impedances for experiments in which statistical power too minimum. Using intelligent circuit design and high quality instruments this noise can be eliminated.

B) Movement Artifact- On activation of the muscle, its length decreases and the muscle skin and electrodes move with respect to one another. Such type of artifact is movement artifact.

C) Electromagnetic Noise- The surface of the human body is continuously inundated with electric and magnetic radiation which is the source of electromagnetic noise. So such a noise sources from the environment superimpose the unwanted signal or cancel the signal being recorded from the muscle.

D) Crosstalk is an undesired EMG signal from a muscle group that not commonly monitored. The signal can be corrupted and cause an incorrect interpretation of the signal information because of crosstalk. It depends on the many physiological parameters [11],[2]. Its value can be reduced by choosing proper size of electrode and inter-electrode distances carefully.

E) Internal Noise-These are anatomical, biochemical and physiological factors take place due to depth and location of active fibers, the amount of tissue and the number of muscle fibers per unit.

F) Inherent instability of signal - The nature of EMG signal is quasi-random. The frequency components between 0 and 20 Hz are mostly unstable because firing rate of the motor units affects them. Because of the unstable nature of these components of the signal it is considered as unwanted noise. The numbers of active motor units, motor firing rate and mechanical interaction between muscle fibers can minimize it.

G) ECG artifact –For surface electromyography (sEMG) in shoulder girdle, the electrical activity of the heart creates disturbance considered as ECG noise. It often corrupt EMG signals particularly in trunk muscle electromyography. The arrangement of EMG electrodes is depend on the selection of pathological muscle group, decides the level of ECG artifact in EMGs. Due to an overlap of frequency spectra by ECG and EMG signals and their relative characteristics, such as non-stationarity and varied temporal shape, it is very difficult to remove the ECG artifacts from the EMG signal.

IV. ARTIFACT REMOVING APPROACHES

Varieties of artifacts in recognition of EMG signal are major problem. Hence, the necessity of removal of noise in EMG signal becomes most significant.

The different EMG signal processing techniques with advanced methodologies has become important in recognizing the speech signal with accuracy. Some of the methods of signal processing are listed below [9],

A) Wavelet Analysis - There are many approaches in time and frequency domain that has been attempted in the past. For local analysis of non-stationary and fast transient signals, the wavelet transform (WT) is an efficient mathematical tool. The most probably, properties of WT can be implemented by the discrete time filter bank. The Fourier transforms of the wavelets are referred as WT filters. This is a very suitable method for EMG signals classification.

B) Higher Order Statistics (HOS) - This is a technique for analyzing and interpreting the characteristics and nature of a random process .It is based on the theory of expectation as the probability theory. HOS spectrum also has the sum of two or more statistically independent random processes equal the sum of their individual HOS spectra. Therefore, HOS can extract information due to derivation from Gaussianity to provide suitable measurement of the extent of statistical dependence in time series [4].

C) Empirical Mode Decomposition (EMD) – For the analysis of non-stationary and nonlinear signals this is a moderately new, data-driven adaptive technique. EMD is a method to analyze the underlying notion of instantaneous frequency. This method also focuses into the time-frequency signal features. The EMD method also calculates intrinsic mode functions (IMFs).

D) Artificial Neural Network (ANN) This method is not very popular for EMG signal processing for noise reduction. The Neural Network (NN) approach is suitable for modeling nonlinear data and is able to cover distinctions among different conditions. The requirements for designing an ANN for a given application include: (i) defining the network architecture; (ii) determining the total number of layers, the number of hidden units in the middle layers and number of units in the input and output layers; and (iii) the training algorithm used during the learning phase [1]. The back propagation neural network (BPNN) is a popular learning algorithm to train self-learning feed-forward neural networks.

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E) Independent Component Analysis (ICA)

In EMG signal processing techniques, ICA algorithm has rapidly become one of the most prominent approaches. ICA is a statistical method, which can assume the original signal from the mixture signal. This is a linear transformation used to obtain independent components within a multi-channel signal. The idea behind is that the statistical independence between the estimated components is maximized. ICA run on the raw EMG signal and decomposition matrix is computed separately for arrays. In [7], develop a heuristical measure to determine whether any detected component should be considered an artifact or a target EMG signal component. For example, Fig. 2. shows recorded EMG signal from the setup along with their ICA decomposition.[5]

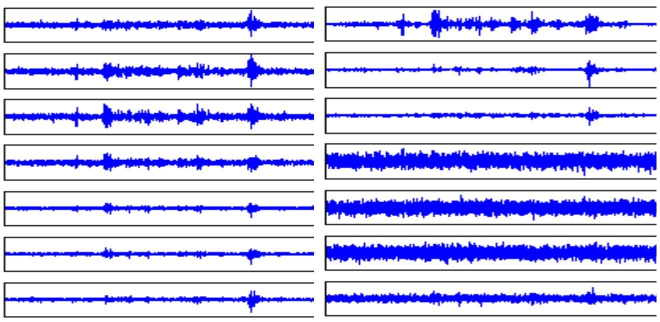

Fig. 2. EMG signals obtained from the setup before ICA processing (left) and after ICA processing (right)

In Fig.2, 7 original EMG signals (left) were captured from the chin array. These signals were then decomposed into 3 original signal and remaining 4 noise signals. The elimination of noise channels improves the recognition results. Two strategies were developed,

1. Direct method –This method involves using the ICA components, detect and eliminate the noise components.
2. Backprojection – This method is same as direct method with the addition that the components are back projected to the original signal. This process is mathematically represented as performing ICA decomposition, setting artifact part to zero and then multiplying these components to the inverse of ICA matrix.

$$X=As \qquad (1)$$

Equation (1) represents an ICA model.

Where $X = [x1, x2\ldots xm]^T$ is an m vector of linear mixtures, $S = [s1, s2,\ldots,sn]^T$ is an n-dimensional random vector of independent source signals, and A is full-rank m × n scalar linearly mixing matrix (n × m). Without knowing the source signals and the mixing matrix, a signal copy of the statistically independent sources s will be estimated from observed mixtures x. In this Fig. s (t) are the sources. X (t) are the recordings sˆ (t) are the estimated sources, A is the mixing matrix, and W is the un-mixing matrix. The independent sources must be strictly non-Gaussian. It is suitable to separate the EMG signals from different sources. ICA is a feasible method for source separation and decomposition of an EMG signal. ICA algorithms are widely used to separate and remove artifacts from EMG and to decompose EMG signals into a maximum number of independent components. The block diagram of blind separation technique is shown below,

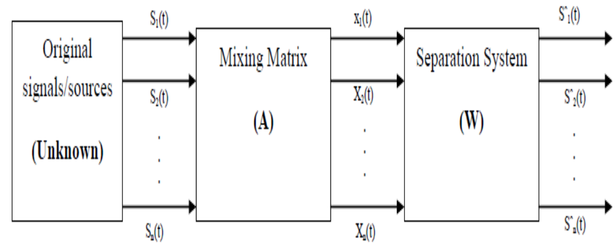

Fig.3. Blind source separation (BSS) block diagram [11]

The different types of ICA algorithms used for processing the EMG signal are the Fast ICA algorithm, the Joint Approximate Diagonalization of Eigen-matrices (JADE), and the Infomax Estimation or maximum likelihood algorithm. The Fast ICA algorithm yields simplicity, fast convergence and satisfactory results.

The fast ICA algorithm is classified into two types: Fixed-point algorithm for one unit, and Fixed-point algorithm for several units. Word Error Rate (WER) is a performance parameter defined by [5] which improves accuracy.

V. DISCUSSIONS

This study showed that several undesired signal sources i.e. extrinsic factors, inherent noise in electronic equipment, motion artifacts, and ambient noise can be attenuated to a great extent by using an active electrode. This was the basic technique used before, but nowadays it is not sufficient for the noise elimination problem. This paper focuses on different EMG signal processing techniques such as Wavelet Analysis, Higher Order Statistics (HOS), Empirical Mode Decomposition (EMD), Artificial Neural Network (ANN) and Independent Component Analysis (ICA). The EMG signal quality can be improved by using the above signal processing techniques. Hence the signal becomes more accurate, simple, reliable, steady and appropriate for further use in SSI.

VI. CONCLUSIONS

A raw EMG signal gives very important information regarding the nervous system in useless form. This signal is obtained as an input signal with the help of combination of array setup placed on the face as discussed in section 2. This paper was to give detailed information about different types of noises and artifacts from EMG signals, and to explore the various methodologies for analyzing the signals. The ICA method is discussed in detail. This method determines WER which improves EMG signal quality.

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