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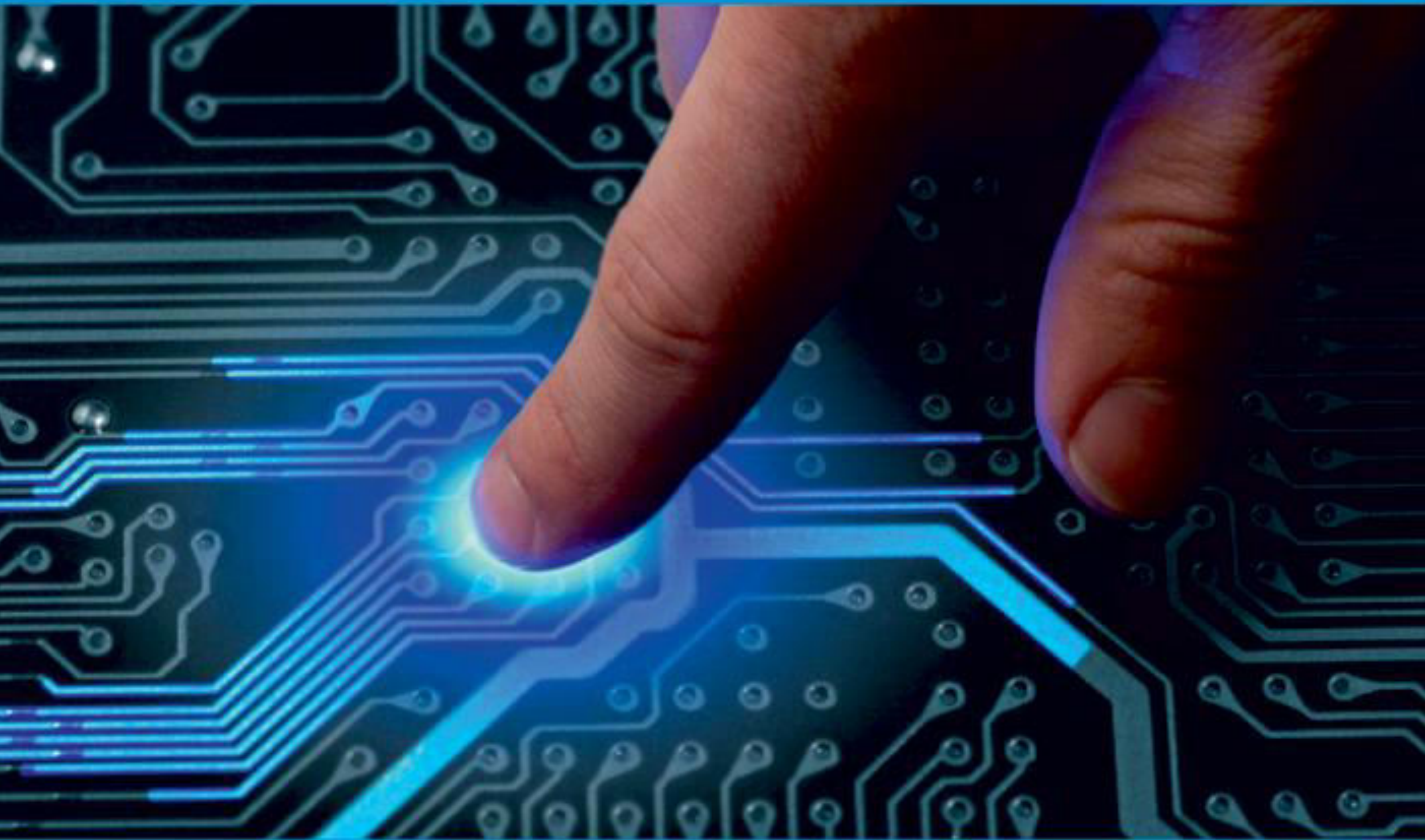

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Subvocal Recognition Using EMG

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ABSTRACT: Speech is the most natural method for humans to communicate is a good idea to use it with no issues in all aspects of human life. However, this is not feasible in some situations, such as unsuitable environments or speech impairment individuals. Unvoiced speech recognition can solve these problems by acquiring biological signals directly connected to speech. Therefore the analysis of systems for silent speech recognition based on electromyographic signals is described. The applications of this technology in human interfaces, and medicine, including the voiced and unvoiced award, are presented. A description of the hardware and software utilized in EMG-based applications is given, and an introduction to the techniques used to extract features and classify myographic data. The outcomes obtained by other projects are reviewed, and these systems' most significant issues faced are discussed. Subvocalization occurs as subjects read or think, distinguished by involuntary facial and laryngeal muscle movement. When we measure the activity of these muscles through electromyography on the surface (EMG), it could be possible to implement automatic speech recognition (ASR) and allow for the use of hands-free, silent human-computer interfaces. We tackle the challenges that arise from insufficient data, including vague generalization, by using the augmentation of electromyographic data to identify promising avenues to pursue in the future.

I. INTRODUCTION

Speech-related impairments can impair the effectiveness of systems for speech recognition. Furthermore, it could be highly dependent upon actual conditions, such as the level of noise in the environment and the echo. The systems are built upon "audible speech" that is not robust enough for applications like over-space communication. Speech recognition is a vital component of human-computer communications. The most popular methods used for speech recognition are built into the study of an audio signal. The signal could be represented in real-time or previously recorded data using natural speech sound.

The application of acoustic signals analysis is only sometimes possible. In noisy environments, it is impossible to distinguish any noise from speech. In this scenario, the limitations of technological capabilities are evident. On the other hand, it is impossible to use voice communications in a quiet space due to the requirement to preserve silence. In both situations, additional signals produced by a system for speech articulation could be beneficial.

There is a possibility to record Electromyography (EMG) signals that are produced by muscles in humans' speech organs. Low voltage levels distinguish them and, thus, are difficult to capture. Another issue is their low resistance to interference from outside due to the necessity for high gains. In order to make the most of EMG signals, it is essential to record and enhance them.

In order to make the most of EMG signals, it is essential to record and enhance them. The second part of the article describes basic assumptions and the implementation of recording devices. Additionally, the outcomes of the initial attempts to utilize the device are explained.

II. MOTIVATION

Automatic Speech Recognition (ASR) is now a well-known technology. It is currently being used in various daily life applications, such as a personal system for dictation, as all c, mobile phones.

While there are many benefits of a traditional speech-driven interface to us, it has three significant disadvantages:

First, it is essential to note that the audible (i.e. an acoustic) speech signal is a deterrent to a private conversation between or on devices. In addition, conversations are a very irritating experience for teethers, particularly in meetings or in libraries.

Second, speech recognition performance decreases dramatically in harsh environments, such as automobiles, restaurants or even trains. Acoustic model adaptation can mitigate these effects to a certain extent, but the overall design of smartphones can thwart this method. The performance also suffers when there are limitations to sound production in water, for instance.

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Conventional interfaces that use speech cannot be utilized by speech-impaired individuals, such as those who lack vocal cords. To overcome these issues, alternatives are being studied that does not rely upon an audio signal to perform ASR. Chan et al. [Chan and co. 2002b] showed that the myoelectrical signal (MES) of the articulatory facial muscles has enough information to distinguish a word set accurately (>90 per cent word accuracy on the 10 English numbers). This is even true when words are spoken without audible, i.e.; no acoustic signal is generated [Jorgensen and co. 2003[Jorgensen et al., 2003]. The advantage of electromyography (EMG) speech recognition lies in its ability to recognize speech that does not depend on transmitting an audible signal. It permits private, non-intrusive communications in any setting and may be used by people with speech impairments.

Furthermore, it is resistant to noise from the environment. However, to date, the practicality of MES speech recognition is not yet fully realized:

1. The electrodes on the surface have to be physically connected with the skin of the person speaking.
2. Research is limited only to isolated recognition of words.
3. Current systems are unreliable, as they can only function in a manner compatible with training and testing conditions.

Like traditional speech recognizers, the MES system is strongly influenced by the speaker's dependencies, including speaking style, speech rate and pronunciation idiosyncrasies.

Additionally, the myoelectric signal can be affected by slight variations in the electrode's position, temperature or tissue properties [Lamb & Hobart 1992(Lamb & Hobart, 1992). We refer to this issue as session-dependent, compared with the dependence on a channel of the conventional speech recognizer, which is caused by the quality of the microphone, noise from outside and transmission of the sound signal. Therefore, there are significant challenges to overcome. In the next section, we present the goals we have established for this project so that we can assist in the advancement of the latest technology.

III. GOLES OF THIS PROJECT

The objectives of this project were to Create a cutting-edge speech recognition system built on myoelectric signals to address the significant problems in the field of novel technology that has not been addressed in the literature, and to prove the practicality to show the efficacy of EMG for speech recognition, to prove its efficacy.

IV. SUBVOCAL RECOGNITION

Subvocal Recognition (SVR) is an idea of synthetic telepathy that aims to convert sub-vocalization to speech or digital text. The idea is to use electrodes connected to the throat that can sense electrical impulses. Electromyograms are generated by these electrodes, which are processed to produce either text or audio output. The user does not have to talk or speak to allow the system to function. This opens up a vast opportunity for underwater or space communication applications, as well as other areas in which speech is unsuitable. Electromyograms differ for every human. Therefore, it is not easy to pinpoint the optimal location for electrode placement. Researchers are trying toto improve methods to determine each individual's electromyogram accurately. The technology is in its infancy and requires significant progress before it can be used in the real world.

The University of California is currently conducting research with Subvocal Recognition and has made significant progress in this technology, thanks to the funding of the U.S Army. NASA is also believed to be involved in this research. With massive potential applications across various significant areas of defence, science, and healthcare, the technology is predicted to receive significant investments over the next few years, which will drive the market.

In two years, the technology that allows users to speak and not make an utterance could become commercially accessible. The ability to communicate in silence can be helpful in daily situations, like conversations on the phone on an overcrowded train or any time we would prefer that people would not be able to hear us. It could help with security forces and special operations and people with difficulties with their vocal cords and may even be used in gaming.

Seven years ago, a modest NASA research program focused on creating the capability to record, analyze, and reconstruct subvocal speech was launched in NASA's Extension of the Human Senses program. The subvocal research on speech recognition directed by Prof. Dr Charles Jorgensen initially focused on developing speech enhancement and silent communication in noisy environments, such as NASA's space stations. It was soon apparent that the technology had several other applications, too. It could also assist bodyguards, security personnel or Special Forces in highly secretive operations to avoid detection in highly secure operations. For the tank, commanders can issue commands even in noisy fighting situations.

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V. CONCEPT OF STSTEM

EMG SIGNAL SENSOR: The design of the hardware component that makes up the SVR (subvocal recognition) system must conform to certain assumptions due to the particular features of signals:Excellent quality of the signal path due to the use of low-level signals distinguished by the absence of noise and high dynamic and resistance to interference from outside sources.

Flexibility in the design of the path for different signal electrodes used and different kinds of electrodes, as well as possibilities of simultaneous usage of different signal paths.

Mobility - the portable nature of the system, its small dimensions, and its weight.

Based on these assumptions described above, a block drawing of the system was created (**Figure 3.1.1**). The requirements necessary for its components have been identified.

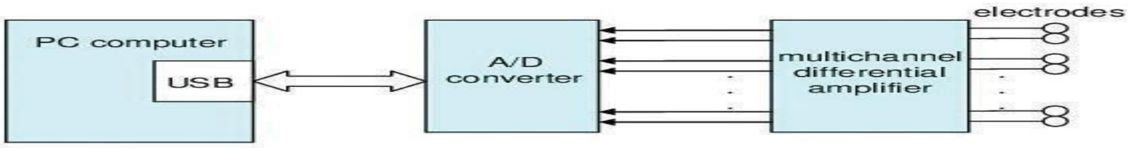

Figure 3.1.1: Block diagram of subvocal system.

The properties of the electrodes utilized in the study were determined in part based on SENIAM (Surface Electromyography to Facilitate the Non-Invasive Evaluation of Muscles) recommendations [44. According to SIAM, bipolar electrodes are available. Due to the tiny size of the muscle being studied, The electrodes need to be located close to the muscle.

Muscles. Additionally, the electrodes should be small. Electrical impulses gathered by electrodes should be amplified between 500 and 1000 times. To achieve this, it is essential to employ specially-designed low-noise amplifiers because of the use of bipolar electrodes, the amplifier functions in a different mode that can significantly minimize the effect of external noise on the recording signal. For additional analysis of EMG signals, it is required to substitute electrical EMG signals using digital versions. This procedure allows the digital process of EMG signals in computers. The conversion process that transforms analog signals to their digital format calls for using an acquisition card for signals (DAQ card). Due to the necessity of mobile systems, the best option is to utilize an external adapter with a USB interface. It allows the use of portable laptops, and it is not necessary to buy additional power supplies as the power is provided via this USB port. One of the most crucial components in the setup is a personal computer. This device houses the SVR software based on electromyography signals that can be installed.

ELECTRODES: The components that collect electromyography signals are electrodes. The device uses different types of electrodes to provide the most suitable solution. The self-adhesive electrodes (**Figure 3.2.1**) offer excellent flexibility for a specific subject. This type of electrode allows them to be placed nearly everywhere. Initial tests have revealed that adhesion to these electrodes can only be achieved on dry, smooth skin. Hairs that are present that are on your skin and sweat and wrinkles can hinder the electrodes from adsorbing.

Figure 3.2.1: Self Adhesive Electrode.

A different option is to utilize cup-shaped electrodes made of metal (Figure 3.2.2). They also have isolated electrodes that make them suitable for any deployment. They require the use of a special adhesive conductive gel, which is used to fix the electrode. It also improves your connection's conductivity. The electrodes can be made from various substances, like silver, or silver is coated by silver chloride (Ag/AgCl), iron, gold or tin. Because of their excellent properties - stable and low in terms of time voltage, the most frequently used are silver electrodes coated by silver chloride.

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Figure 3.2.2: Cup shaped metal electrode.

Individual electrodes have the advantage of being able to place anywhere, but in some cases, it can be a problem. This happens when repeatable electrode placements are required in order to couple them. The bar-type bipolar electrodes (**Figure 3.2.3**) are a good option in such cases. These electrodes are compact and have lead shielding. Their structure strongly determines the distance between electrodes.

Figure 3.2.3: Bar type bipolar electrode.

A reference electrode is required for measurement. The additional electrode's purpose is to determine the speaker's reference potential. The additional electrode is necessary to determine the reference potential of the speaker. Without it, noise from the power network and other sources can cause the measurement to be halted. The reference electrode is attached to the patient at a location where there is no muscle activity during the measurement.

AMPLIFIER: Specially designed amplifiers are used to amplify the EMG signals generated by the electrodes [5]. The amplifier is ideally suited for SVR purposes because of the design of the systems.

These are the guidelines for amplifier design. They are based on the following:

The frequency band should fall within the range of 10 to 500 Hz. Therefore, filters should be used to limit the frequency range.

The total amplifier factor must be highly high (upto 1000 V/V).

Assume a self-noise of less than 1mV about the input signal.

It is essential to obtain the highest possible value for CMRR (standard mode rejection ratio) to suppress interference from outside. Assume that CMRR > 95 dB.

EMG amplifiers have an input impedance of at least 10 MO. The high resistance of human skin and the non-ideal coupling between electrodes and skin and adipose tissues make EMG electrodes' impedance significant. It can reach several hundred kiloohms. It is possible to achieve maximum EMG voltages due to the amplifier's high input impedance.

External distortions can be reduced by reducing the length of the cable connecting electrodes to amplifiers. Therefore, amplifiers should be placed as close and small as possible.

The power supply for the amplifier can be found on the DAQ cardboard. Therefore, an additional power unit is not required.

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Figure 3.3.1 shows the scheme of an EMG amplifier.

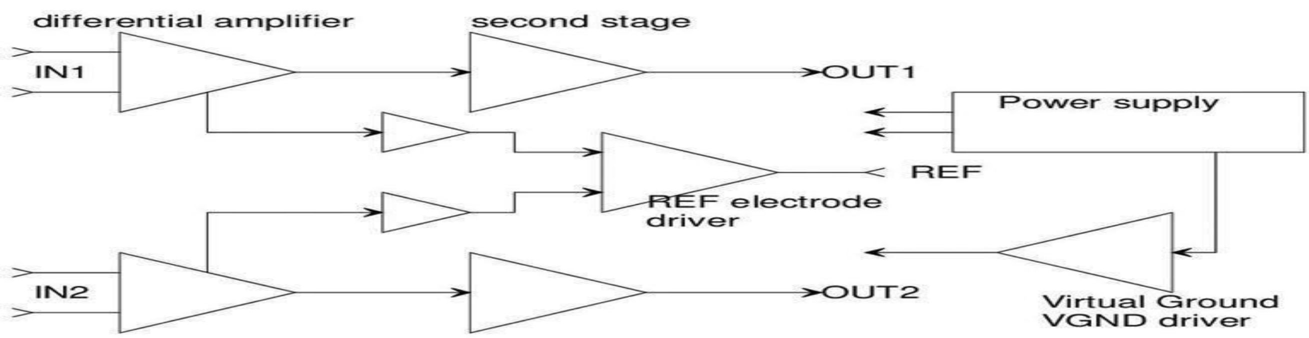

Figure 3.3.1: EMG Amplifier.

DRIVER DURING THE REFERENCE ELECTRODE: The reference electrode's task is to fix the patient's potential and ensure returns to the bias currents in a differential amplifier. The driver increases the damping of the common amplifier component (CMRR), which can be adjusted from 10 to 50dB [6, 7, 8]. This system works by continuously comparing the average voltage of measuring electrodes to the virtual ground. Any difference is amplified with an opposing sign and then put to the reference electrode. This ensures that the DC component of the measuring devices is maintained at the correct value. To increase the CMRR of an instrumentation amplifier, the reference electrode driver (RLD) is used. This higher signal-to-noise ratio (SNR) ensures that the differential signal is only relevant and contains minimal interference currents.
The RLD's purpose is to maintain a voltage potential in the subject directly connected to the system ground. This reduces the standard mode DC offset in the system and attempts to cancel any other DC offsets individual probes or channels may experience. The RLD's actual process is unique. The feedback network is built using the intermediate inputs of the combined instrumentation amplifier floating ground and the GROUND signal from the human. The signal is sent to an inverting gain stage that completes the feedback loop. This effectively counteracts any possible changes in the subject.

VIRTUAL GROUNDSOURCE: All electronic circuits in the power amplifier receive a single voltage. Therefore, an artificial ground potential was required. The DC voltage of this virtual ground should equal half of the supply voltage. This is easily achieved using a simple resistive divide (the same version used to build the first amplifier). The voltage can change due to the current changing from the divider. The buffer amplifier was added to the second version, which keeps the potential for virtual ground unaltered**.**

ADC Card (DAQ): The DAQ card parameters can be simply due to the small bandwidth of the collected signals and the high signal level after amplification.
The external card must have a USB interface to allow mobility of the entire system. The precise sampling requires high dynamics and a resolution of at least 16 bits. The original multicard system must allow for sampling at least eight channels. It is optional to determine the sampling rate. The sampling rate is sufficient to reach 4 kHz at the highest frequency of the analyzed signal, 500 Hz. The total frequency of the entire card, even with eight channels, will be only 32 kHz
Switched ranges are a desirable feature of this card. These ranges allow for a more flexible adjustment of the amplitude of sampled signals and better use of dynamics DAC.
This project's software is written in C++ and runs on Linux. The application was successfully tested on Linux Debian. Due to licensing requirements, it is now a console program. The software's primary goals are data acquisition, signal parameterization and classification.

VI. EMG MEASUREMENT USING CUP SHAPED ELECTRODES AND DOUBLE GLUED ELECTRODES

Measurements were taken using adhesive (Figure 2.2.1), cup-shaped electrodes (Figure 3.2.2), and double electrodes. (Figure 3.2.3). Figure 3.2.1 shows the reference electrode used to glue the other electrodes. Figure 4.1 shows an example of how to place the reference disc electrode.

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Figure 4.1 Example of reference disk electrode placement

SYSTEM OF MEASUREMENT: *The measurement system includes electrodes, a preamplifier for an EMG signal, an AD converter, and a multichannel recording device. A multichannel recorder or sound card with software for digital signal processing has been used as an AD converter.Before finalizing the configuration of this measurement system, a few additional features were checked. Five different methods are used to record the measurements.These measurement configurations were used. Three of the configurations were deemed unacceptable. The main issues are the interference from the power supply, noise from FireWire (not all the time), and demodulation of EMG signal cables from nearby radio station transmitters. These problems were eliminated by using battery power, reducing the length of EMG wires, and using the USB bus.The EMG signals were saved as wave files with a 48-kHz sampling rate and 16-bit resolution. The EMG signal dynamics are approximately 20 dB. Therefore, the signal parameters can be sufficient. A wave format file allows for easy analysis of recorded signals. The recorded signals can be observed during measurements and displayed in real time. You can also insert markers to highlight the words in the next repetition. The results of the measurements are illustrated in Figure 7.*

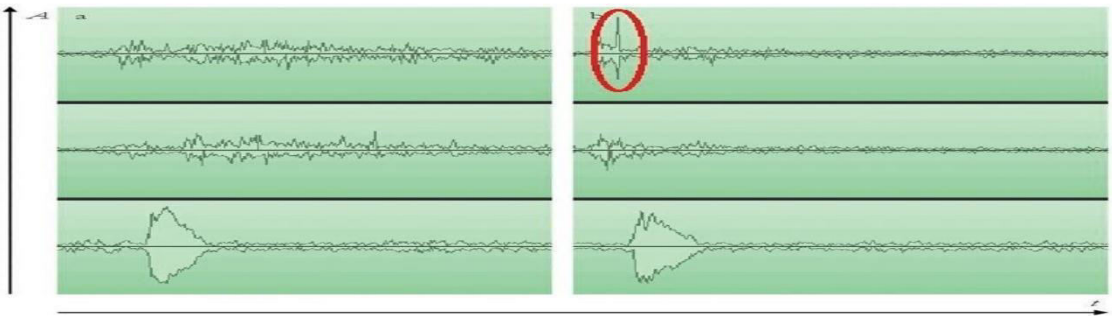

Figure 4.1.1 Some measurement results.

A sample measurement result for a person using a standard EMG signal (vowel "a"): a) A valid signal; b) An interference signal (marked). The top:An EMG signal from a bar-shaped electrode. A cup-shaped electrode EMG signal. An acoustic signal was recorded using a microphone. A - amplitude (arbitrary units), and t - the timing.

VII. STATE OF THE ART OF EMG SPEECH RECOGNITION

Research in electromyography was limited to speech technology (parameters comparison of prosthetics and healthy people).In 1985-1986, the USA and Japan conducted significant trials of EMG for automatic speech recognition. Morse et al. [8] used four-channel electrodes with a sampling frequency of 5120 samples/channel/s. After limiting the frequency band and amplitude to 100-1000Hz, 20 repetitions were made of isolated words (digits) for each of the two voices. Scores of 60% were achieved after using maximum likelihood (ML). The same team also obtained similar results using neural networks [9].In a parallel study, Japanese scientists Sugie et al. [10] used three-channel electrodes with a sampling rate of 1250 samples/channel/s to perform real-time phone recognition experiments. They correctly classified 50 Japanese syllables and three voices at 64%.

The NASA Ames Research Center is one of the top research centres for subvocal speech (based upon EMG). Jorgensen et al. Wavelet transform and linear predictive coding are used as parameterization methods. They also use artificial neural networks and support vector machines, SVM (Support Vector Machines), and HMM [hidden Markov model] as classifiers. They were able to get scores in the range of 90% for the five limited voice commands. The scores for the English phone and female voices were at 50%. NASA has included speech recognition in difficult situations among its applications. This includes voice commands controls (e.g. for remote steering an application or robot) and acoustic speech recognition - with high noise levels or speech pronounced when the gas mask is on.

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Schultz and colleagues. [13 - 15] At Karlsruhe University, research can be considered the most important in the past decade. They tried to overcome speaker dependence and the limitations of the data. Six electrodes were placed on the neck and face of the speakers to record the collected signal database (EMG–PIT). The parameters of the time domain (mean value, energy, and crossing zero density) were used to parameterize the signal. They obtained 47.15% WER (word error rate) for the 14 speakers (10 sentences each).

VIII. AUTOMATIC RECOGNITION TEST

Figure 6.1 shows the block diagram for general speech recognition procedures. The system also uses the signals stored in the EMG signals library. The front-end procedure's task is to take a parametric picture of the digital EMG signal registered and then recognize it in the classification process. There are two phases to the classification process: recognition and training.Preliminary tests were conducted for EMG recordings of six Polish vowels (a,e, i,o,u,y] and eight words [stop/start, dalej. V levo, VA pravo. Pauza. Enter, tac]. Vowels and words are listed in the SAMPA(Speech Assessment Methods Phonetic Alphabet) notation. The test material was recorded using two types of electrodes: self-adhesive and cup-shaped. The problem of speech recognition using the EMG signal is still new. There is, therefore, no standard set of best features.Many features described and applied in the literature are based on modern speech recognition techniques that use acoustic signals. Although the EMG signal has a different physical origin than the acoustic, it has an entirely different nature in terms of frequency (limited to substantially less frequency range) as well as time domain (longer intervals due to relaxation and preparation of muscles for each utterance). It takes work to select the most compelling feature set. This requires more research and testing. The feature vector was a combination of LPC (linear prediction coefficients) and spectral frequency cepstral coefficients. The following tests showed that the parameters were used (average and deviation): 13 MFCC and 10 LPC, five spectral moments and 10 area methods for moments of MFCC. LPC and MFCC are the most commonly used features in speech technology. Additionally, the FFT (fast Fourier transform) moment was usedto account for spectral variability and its modification for MFCC.

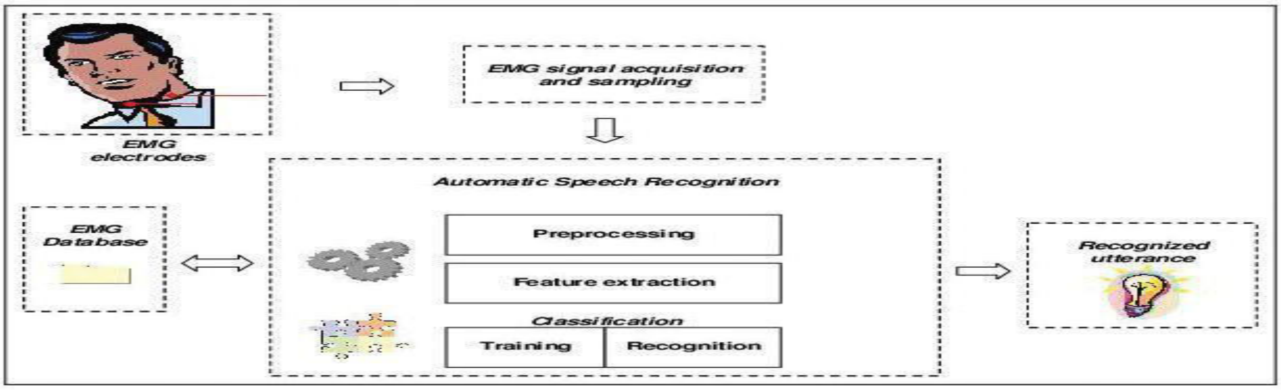

Figure 6.1 Block diagram of speech recognition procedures.

IX.CONCLUSION

The EMG signals from the electrodes can further analyse most cases.Subjects who did not receive the correct EMG signal during the first trial may be able to learn how to use such words to record the signal. It was possible to speak the words after a few minutes of training correctly. The EMG signals could then be recorded. The way words were spoken was unnatural and expressive.The research subjects can be broken down into three categories:People could speak in such a way that registered EMG signals could allbe recorded at once. You can record signals with a greater amplitude using expressive facial expressions.After training, people who could produce sufficient EMG signals to record them. You can capture data with average values using expressive facial expressions.EMG signals are not registered in the case of people who have neverbeen trained.It took much work to get uninterrupted EMG signals. The EMG signalparameters reflected each speaker's movement. The signal generated by salivary reflexes, which can cause interference up to three times higher than the speech signal, was powerful. It is crucial to establish the proper measurement conditions, separate from the power supply and any other signals that electrodes can easily pick up.
Automatic recognition tests gave the Bayes network the highest scores, although the differences among the classifiers were not significant. Vowel recognition and words had very similar results (in

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vocal speech signal recognition, vowel recognition would get better results than word recognition).The differences between electrodes indicate that the effect of electrodetype and location can significantly influence final scores. Both electrode types were recorded during the same recording session. Vowel recognition was affected by a significant difference of around 10%. In the case of word recognition, it is insignificant. A speaker-dependentcase and session-dependent cases can lead to significant increases in correctly classified instances.

X.FUTURE SCOPE

Subvocal recognition is a related technology, but at a much earlier stage of development. It converts electrical signals from the throat to speech without the operator making a sound. This technology could be used for pilots, firefighters, SWAT teams, and special forces. It could input information in harsh or noisy environments, underwater, and in space. It has been used to control a motorized chair and may be an efficient method of speech synthesis for those with speech impairments. It could also be used for recreational purposes. Subvocal controls will be adopted by the gaming community almost immediately after they are commercially available. NASA Ames Research Center is developing a subvocal system for astronauts' EVA suits. Chuck Jorgensen (the project's chief scientist) suggested that subvocal control technology might be commercially available within a few years.

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