Hands-Free Electrolarynx Device Controlled by Neck Strap Muscle Elecromyographic Activity

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ABSTRACT

Total laryngectomy surgery results in a loss of human voice, and a corresponding deficit for normal speech production. A key disadvantage of available voice replacement prostheses is the inconvenience of using one hand for operating the device when speaking. To address this problem, a hands-free portable electrolarynx (EL) was developed. This wearable device transforms neck muscle electromyographic (EMG) activity into control signals for initiation and termination of voicing. Using the new system (EMG-EL), seven normal subjects produced voice initiation that was as fast as with a commercial hand-held EL, and faster than with normal voice.

1. INTRODUCTION

Human voice is the foundation of self-expression and vocal communication with others. Unfortunately, each year thousands of people undergo a laryngectomy, which is the surgical removal of the larynx for the treatment of cancer or trauma. Loss of the larynx results in the inability to produce normal speech and the need to breathe through a hole (stoma) in the neck. However, since the main articulators are still intact, a prosthetic device can be used to acoustically excite the vocal tract for production of alaryngeal speech.

There are three alternatives for people to regain their speech. The first method is esophageal voice. The second method is tracheo-esophageal voice, The third method is the Electro-Larynx device (EL). The use of the TE valve allows for more functional speech that is easier for patients to produce. However, due to a variety of surgical, morphological, and behavioral factors, only about a third of laryngectomy patients can use it successfully [1]. Thus, EL speech continues to play a major role in laryngectomy rehabilitation, with multiple studies reporting that over half of the laryngectomy patients use an EL for verbal communication .

1.1 SYSTEM MODEL

EL speech continues to play a major role in laryngectomy rehabilitation, with multiple studies reporting that over half of the laryngectomy patients use an EL for verbal communication. A hand-held EL is composed of three parts: a transducer that mechanically produces the sound, an electric circuit that drives the transducer, and a battery pack that provides the power. On/off control has been typically achieved using a button-switch.

2. WORKING OF MAIN UNIT

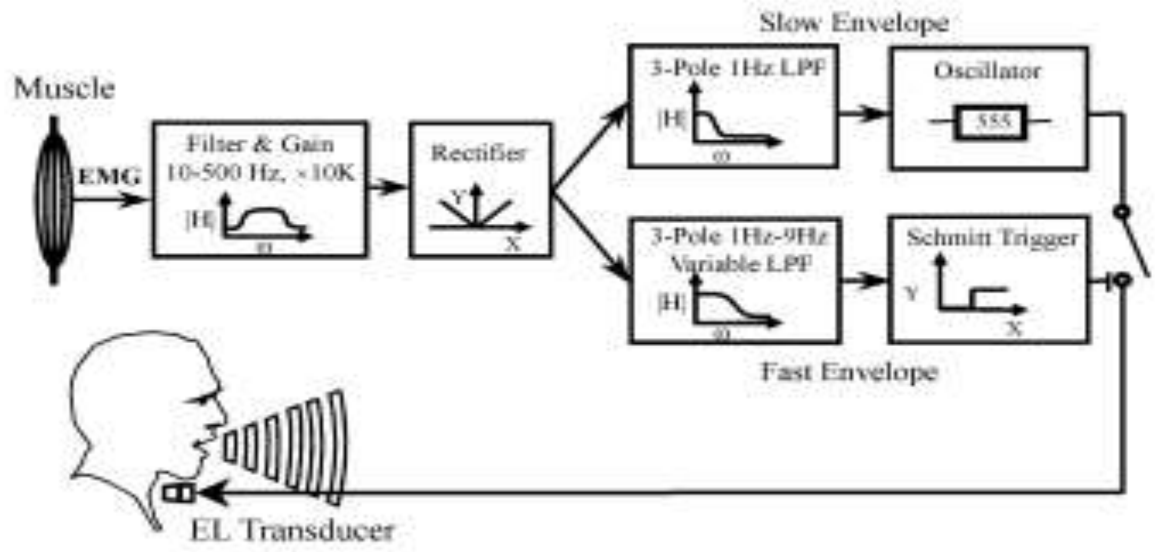

Fig. 1. Processing stages of the EMG-EL processor: EMG signal is filtered and amplified, then rectified and smoothed to produce a slow envelope (top path) to modulate pitch, and a fast envelope (bottom path) to control on/off of the EL.

A schematic representation of the EMG-controlled EL system (EMG-EL) is shown in Fig. 1. The EMG processing circuit produces an envelope waveform proportional to the time-averaged power in the EMG signal. The time-varying envelope controls on/off triggering and fundamental frequency (pitch) of a commercial EL transducer ,which is held against the neck with a simple brace.

The electrical activity of the infra-hyoid neck strap muscles is detected on the surface of the skin using a bipolar electrode. The EMG signal amplitude is on the order of tens of microvolts, with most energy in the frequency range of 10 to 500 Hz. Therefore, the EMG signal is amplified and bandpass filtered to increase signal-to-noise ratio (SNR). The signal is then actively rectified and sent through two parallel pathways, each with a 3-pole low-pass filter (LPF). The first LPF has a corner frequency of approximately 1 Hz, while the second has a variable corner frequency that could be adjusted from 1 to 9 Hz. The two pathways produce two envelopes with “slow” and “fast” time constants. The fast envelope is fed to a Schmitt trigger to turn the transducer on and off based on a controllable threshold voltage. Simultaneously, the slow envelope is used to control the fundamental frequency of EL voice by directly modifying the frequency of the oscillator driving the EL transducer. The other parameters of the EMG-EL processor are EMG gain, EL volume, starting fundamental frequency, and corner frequency for the fast-varying envelope. This paper will discuss voice initiation and termination, but not control of fundamental frequency.

3.RELATED WORKS

I. The conventional EL design is very limited in terms of practicability and usability. Due to the coil-coupler disk setup the artificial excitation waveform can only be changed to a limited extent. A new transducer should be efficient in terms of both power consumption and acoustic energy production. There are several approaches for the introduction of a new kind of transducer: intra-tracheal devices that use a piezoelectric transducer , or intra-oral devices which are composed of a dental unit, an external unit and controlling electronics . Another intra-oral device used an electro-magnetic transducer . A novel EL transducer, i.e., a light-weight miniature pager motor, typically found in common mobile phones was developed by . Houston proposed a linear, electro-dynamic EL transducer. The new EL sounds more natural than commercially available EL devices, but due to problems concerning the energy supply no further work has been published.

II. The EL device needs to be designed in a careful way as a balance between damping the artificial excitation signal so as to avoid leakage into the surroundings and efficiency in terms of bringing the maximum mechanical energy into the vocal tract. DREL is concentrated in the same range where speech occurs, which causes confusion in vowel separation due to the auditory masking of the vowel formants . It can be either removed using effective shielding of the vibration within the device or using noise subtraction or (adaptive) filtering algorithms . As it turned out, the shielding is only able to reduce the noise to a limited extent and leads only to a minor improvement. Noise estimation based on minimum statistics for spectral subtraction was applied by [20] who formulated an alternative approach of noise reduction in the modulation frequency domain. This so-called multi-path signal separation algorithm is an important part in our work to preprocess EL speech.

3.1 FUTURE WORK

Our experiment shows some limitations of the current prototype. Several improvements can be made by focusing on different excitation signals for female and male users in order to be able to adequately deal with the gender issue. Together with laryngectomees we will further elaborate the speech system, perform requirement analysis and evaluate the bionic EL speech system using human-centered and participatory design based research strategies.

4. CONCLUSIONS

This paper presents evidence that EMG signals from neck strap muscles can be used effectively to control the initiation and termination of electrolarynx voice. The main advantage of the EMG-EL system is its hands-free control, compared to EL and TE speech where the use of one hand is normally required. The
results from the voice initiation data showed that the EMG-EL is as good as normal voice and a commercial EL device, and faster than TE voice. Normal subjects were also able to achieve EMG-EL voice termination that was not different than that produced with a commercial EL. Future work will focus on examining the role that formal training may play in optimizing EMG-EL use, coupled with the evaluation of EMG-EL performance during meaningful vocal speech communication.

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6. REFERENCES

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