Development of Controllable Artificial Larynx by Neck Myoelectric Signal

Katsutoshi Ooe*

Department of Mechanical Systems Engineering, Daiichi Institute of Technology, 899-4395, Japan

Abstract

We developed a novel artificial larynx with on/off and pitch control for Speech Production Substitutes (SPSs) users, particularly an electrolarynx control based on the myoelectric signal of the laryngeal muscles located near the body surface (such as the sternohyoideus). For patients who have lost their vocal cords or its function for vocalization, various SPSs have been developed and widely used. However, these substitutes have the limitation -that they cannot match with the vocalization of healthy human larynx. The measurement of the surface myoelectric potential was performed and we studied its efficiency for voice on/off and pitch frequency control. The results show that there is a quadratic relation between the measured myoelectric potential and the pitch frequency. Using this relation, it was possible to control the pitch frequency of the generated sound in three levels with 86.7% of accuracy (condition of linear relationship lead 68.9%). This confirms that the surface myoelectric potential was a suitable control signal for the artificial larynx. In this paper, the capability of novel controllable artificial larynx controlled by myoelectric signal of sternohyoideus was described.

Keywords: Artificial larynx, Speech production substitutes, Surface myoelectric signal, Sternohyoideus

1. Introduction

Individuals who undergo laryngectomy as a radical treatment for laryngeal cancer lose their vocal cords and their voice; this also occurs with individuals suffering from amyotrophic lateral sclerosis when they are fitted with a respirator.

When voice, which depends on the vocal cords and laryngeal functions, is lost, individuals are deprived of speech, their most important communication tool. This often causes acute mental distress.

* Corresponding author. Tel.: +81-995-45-0604 (ext 3832); fax: +81-995-47-2083.
E-mail address: k-ooe@daichi-koudai.ac.jp.
This has prompted research on speech production substitutes (SPSs) that are classified into 4 categories [1]: the esophageal speech method; the tracheoesophageal (TE) shunt speech method; Tapia’s artificial larynx; and the electrolarynx. However, they have problems with regard to voice quality, articulation, and intonation. For example, the electrolarynx uses an electrovibrator as a sound source, and this method has good features of voice continuity, sound volume, and acquisition. However, it has poor voice clarity because of voiced/unvoiced sound and pitch frequency control. To solve this problem in the electrolarynx, studies are being conducted on the electrolarynx control method [2-3]. Goldstein used the EMG signal for control the on/off of an electrolarynx, but the pitch frequency could not control [4]. All of these techniques focused on controlling the pitch frequency. However, these control methods did not use the laryngeal muscle signals that control pitch in normal subjects. Our research aimed to develop a novel SPS with controllability. We focused on using the electromyographic (EMG) signal of the sternohyoides (SH) to control the electrolarynx. The SH has the function of vocal cord relaxation and is activated during the utterance of low-frequency voice. Therefore, the pitch frequency of the electrolarynx can be controlled using the EMG signals of the SH.

This paper reports the application of the measured EMG signal to control the artificial larynx. The measured EMG signal has a quadratic relationship with voice pitch frequency and the EMG signal appears at the time of vocalization. For development of the controllable artificial larynx, the response of on/off control, the stability of pitch frequency control, the number of errors and the response time for pitch control were evaluated. According to these results, it was clarified that the EMG signal of the SH has enough potential use for the control of artificial larynx.

2. Electrolarynx with On/Off and Pitch Frequency by Neck Myoelectric Signal

Figure 1 shows a schematic diagram of the EMG control-type electrolarynx. The EMG electrode is attached to human neck near the sternohyoides. Its signal is collected to control unit by a wire. For stable EMG signal, the control unit is connected to GND electrode. The electrolarynx is controlled by processing signal by control unit.

![Fig.1 Schematic diagram of the EMG control-type electrolarynx with a compact control unit.](image1)

![Fig.2 Schematic diagram of the cervical muscles and bones.](image2)

Figure 2 shows the major muscles and bones located in the human neck. The important terms for muscles as the control signal of artificial larynx are as follows: 1) activation at phonation (for on/off control); 2) control of vocal cord tension (for pitch frequency control); and 3) shallow location (for
detection by a surface electromyogram). We chose the SH as the muscle to be measured from the muscles shown in Figure 2. The control flowchart is drawn in figure 3. This system has mainly two parts, (a) on/off and (b) pitch frequency control parts.

![Flowchart of signal processing for conversion of the detected myoelectric signal.](image)

**Fig.3 Flowchart of signal processing for conversion of the detected myoelectric signal.**

### 3. Evaluation of Controllability

#### 3.1. Errors in tone control

To evaluate the controllability on frequency change, the indication and height were compared and the errors were counting. The test subject indicate the “High”, “Mid”, and “Low” with his intention. At same time, he takes his mind to generate myoelectric potential. The vocalized sound is displayed depending on the generated myoelectric potential. The error was counting the number of mistakes between two displays from captured video. The relationship function was calculated with linear and secondary expressions.

The failure numbers is shown in Fig. 4 to reach targeted height after presenting his intention. From this figure, it is clear that the failure numbers approximated with linear relationship (b) are higher than one approximated with quadratic relationship (a). This result shows the quadratic relationship (a) has a high controllability.

#### 3.2. Reaction time

To evaluate the response time at changing frequency change, we indicate as visual information to the test subject for selecting “Stop”, “High frequency sound”, “Middle frequency sound”, and “Low frequency sound”. The response time is measured from behavior movie during generating myoelectric potential. The visual indication was presented PC display. The indication pattern was randomly applied. In this experiment, the time valiance was calculated between visual information and start/stop.
The response time of average of visual indication and pitch frequency control is shown in Table 1. From this result, the response time for frequency change was within 1 sec. Hence, the response time of system is short enough, because the proposed system has almost same response time compared with human behavior.

4. Conclusions

In this report, we developed the controllable artificial larynx by neck myoelectric signal. The control signal was detected from the sternohyoideus, one of the cervical muscles, and the availability for control signal was evaluated. From the results, it was described that the processed myoelectric signal could use as the on/off control signal of electrolarynx. In addition, it was clarified that there was a quadratic relationship function between RMS value of myoelectric signal and pitch frequency of vocalized sound. Using of this function, the controllability of electrolarynx was increased in the viewpoint of number of errors. And the reaction time of on/off and pitch frequency change were less than 1 sec, it was enough fast for actual use.

Acknowledgements

A part of this research was performed within Grant-in-Aid for Basic Researches (C) from the Ministry of Education, Culture, Sports, Science and Technology, Adaptable and Seamless Technology Transfer Program through Target-driven R&D, JST.

References

[1] L. D. Lowery, A review: Development of prototype self-contained intra-oral artificial larynx. Laryngoscope 1981;91, 8:1332-1355.
[2] R. L. Goode, Artificial laryngeal devices in post-laryngectomy rehabilitation, Laryngoscope 1975;85, 4:677-689.
[3] N. Uemi, T. Ifukube, M. Takahashi and J. Matsushima, Proposal of an electrolarynx having a pitch frequency control function and its evaluation, Trans. Inst. Electron. Inf. Commun. Eng. 1995;J78-DII, 3:571-578
[4] E.A. Goldstein, J.T. Heaton, J.B. Kobler, G.B. Stanley, et al., Design and Implementation of a Hands-Free electrolarynx device controlled by neck strap muscle electromyographic activity, IEEE Trans. On Biomed. Eng 2004;51, 2:325-332.