A Messurement of Velum Using MRI data and Its Application to Acoustic Model Construction

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1 Introduction

A velum plays an important role in speech production. As widely accepted, it is depressed to open the velopharyngeal port and to produce nasal sounds and elevated to close the velopharyngeal port to produce non-nasal sounds. However, the velum does not only from as a valve for controlling the opening and closing of the nasal-pharyngeal port, but also serves as a vibration source of the nasal branch for non-nasal sounds,which has been proved by Dang. Dang proposed a mechanical model to describe performance of the velum during speech production. Nevertheless, the model has some problems in the proposed model: firstly, all the parameters for the model are inversely estimated from acoustic signals, and the model is not supported by any physiological measurements support his result; secondly, the model takes fixed parameters for all situations, these may deviate in the real situations.

In this study, the model was improved based on measuring related physiological data (the thickness of the velum) from MRI movies, and associating the parameters with variant states (here the states are caccording to vowels).

2 Mesurements based MRI data

2.1 MRI data

Three subjects(H,N,Y)are required to produce meaningless stop-vowel sequences /baba/, /bibi/, /bubu/, /bebe/, /bobo/, /gaga/, and /gigi/, and movements of the articulators are recorded by MRI.

2.2 Thickness of the velum

In the proposed model, the acoustic parameter, L, is related to thickness of the velum. Therefore, thickness should be extracted from the MRI movies. In this study, firstly, thicknesses of the thinnest position(h1) and the thickest position(h2) of the velum are measured, and the average thickness(h) is derived for each frame. Then, the average thickness(H) for each phoneme is estimated as the average of values of the parameter, h, within the duration of phonemes.

The result suggets that: thickness is different among speakers; and thickness is vowel dependent. The velum is thicker when producing a high vowel than when producing a low vowel.

2.3 Relationship between velum thickness and amplitude of sounds radiated from nostril

between velum thickness and amplitude of sounds radiated from nostril is investigated by incoporating the proposed model into of an acoustic tube model. The result suggests that thickness of the velum affects amplitude of the sounds emitted from nostrils when vowels are being produced, while other factors also influences he sounds emitted from nostrils simultaneously when voiced stop are being produced.

2.4 Estimating vibration area of the velum

In this study, a vibration area of the velum is approximated by an ellipse, whose long axis is fixed at 4cm, and short axis is estimated using MRI data. Then, the area of the ellipse is calculated.

3 Incorporating the model into the model of acoustic tube

3.1 Acoustic inductance L for the velum model

An acoustic inductance L is estimated by L=m/S the following formula.

3.2 Estimating other parameters(C_0, R_0, C, R) using Analysis-by-Synthesis method

The inductance of the model is derived from morphological measurements of the velum. However, other parameters are hardly estimated from the morphological data. Hence, an analysis-by-synthesis method is employed to estimate values of these parameters.

3.3 Model simulation

The model of the velum is connected to a model of an the acoustic tube model to synthesize five Japanese vowels /a/, /e/, /i/, /o/, /u/. Spectrum and pressure levels of the synthstic sounds emitted from the nasal branch and the vocal track are consistent with those of real speech. This suggests the model can represent the function of the velum.

4 Conclusion

This study analyzed morphological characteristics in variant states using the MRI data, according the acoustic inductance, L, is calculated under the direction of the mechanic model. Hence, the values of the parameters for the proposed model are estimated with the analysis-by-synthesis method. The results suggest that the model can failthfully realizes the characteristics of the velum.