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Numerical Simulation of the Speaker's Formant for Different Geometric Configuration of the Human Vocal Tract

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Abstract: Various side branches of the human vocal tract exhibit antiresonances and resonances in the human voice frequency spectrum which influence the voice quality. This study investigates the possibility how these specific resonances can contribute to the speaker's formant cluster around 3-5 kHz. A reduced finite element (FE) models were created which allows numerical simulation of the effects of changing the parallel cavities volume on the acoustic resonance and antiresonance characteristics of the vocal tract. These simplified models, created from accurate three-dimensional (3D) FE models of the human vocal tract for vowel [a:,i:,u:], are computationally effective and allow parametric changes of the parallel cavities continuously within the human physiologic range. These changes are expected to play also a role in voice exercising, voice therapy and operatic singing.

Introduction

While the influence of the geometric configuration of the main channel of the vocal tract on the vocal output has been studied rather extensively, the influence of side cavities of human vocal tract, has received less attention. Generally, these cavities have been reported to cause antiresonances in the resulting vocal spectrum, i.e., largely decreasing radiation of some of the spectral frequencies out of the mouth, particularly those around 4–5 kHz [1,2,3,4,5]. As such, their role for the resulting vocal intensity may be considered undesirable, since it contradicts the general goal of enhancing vocal output with the smallest vocal effort. However, newest studies with perceptual evaluation of sound produced using 3D mathematical and physical models of the singers' vocal tracts revealed that the voice quality is perceived as being better when side branches are present.. Furthermore, spectral analysis of singers indicates that the formant structure around 3–5 kHz is more complex than usually expected. A more detailed analysis shows that besides the antiresonances there are also new resonances which occur because of these side cavities.

Computational models

The sophisticated accurate 3D FE models of the vocal tract for vowels [a:,i:,u:,] were created from the CT images. Their usage for investigating the effect of vocal tract shape modifications on the changes in acoustic resonance properties is time consuming. Therefore the reduced FE models were created including all the dominant parallel cavities and their resonance and antiresonance frequencies were tuned to correspond to those of the full FE model. These reduced models were then used for analyzing the antiresonances, resonances and the pressure transfer function of the vocal tract. The accuracy of the results obtained using the reduced models were examined by comparing these to the results obtained by the full 3D FE model.

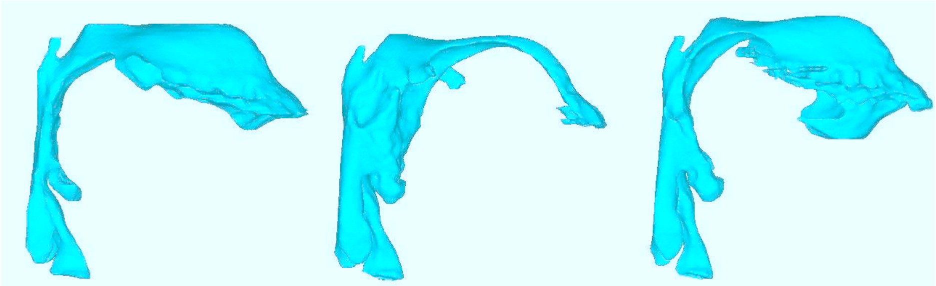

Fig. 1: The geometric configuration of the vocal tract cavities for vowels [a:,i:,u:]

The influence of geometric configurations of the human vocal tract on the generated acoustic pressure was simulated by the reduced FE model shown in Fig. 2.

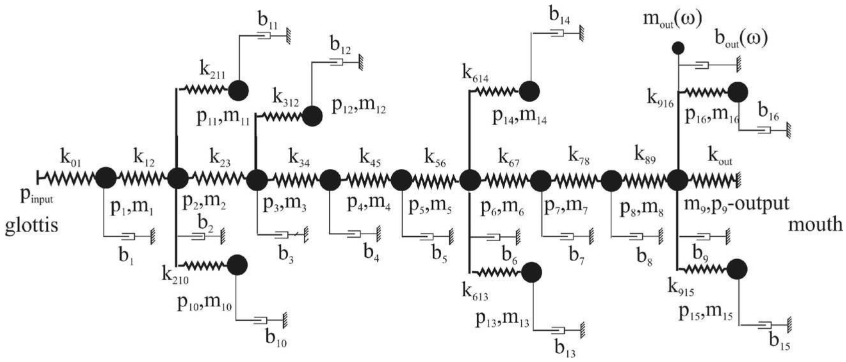

Fig. 2: The simplified reduced model for vowel [i:]

Summary

Based on the numerical analyzes can be concluded that the parallel cavities influence the voice quality for the vowels [a:,i:,u:] by different mechanism. For the vowels [a:,u:] the most important is the increase of the parallel cavities near the human vocal folds. On the contrary for vowel [i:] the phonation characteristics are influenced mostly by the parallel cavities near the tonsils.

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