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Comparison of optimization methods for human vocal tract resonance properties tuning

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Abstract

The paper deals with the two various optimization processes finding such geometrical form of acoustical cavities which leads to excitation of predefined acoustic resonance. A computing times and accuracy of a solutions are compared. The attention is focused both on the first two formants that are important for vowel production, and on a domain between the third and the fifth formant. This frequency domain is important for voice timbre, namely for singing voice. The problem is solved by the help of transfer matrix method using conic acoustic elements. The results should help to have a physical background for voice rehabilitation, for teaching of opera singers at musical faculties and for better understanding of biomechanics of voice production.

Keywords: biomechanics, acoustics, optimization, formant tuning, vocal tract, transfer matrix method

1. Introduction

Theme of the paper is focused on optimization possibilities of geometrical form of human vocal tract. An optimization process is designed to find such configuration of acoustic cavities, respecting real physiological limits, which leads to excitation of predefined acoustic resonance. Especially frequency domain between the third and the fifth formant is important for voice timbre, namely for singing voice ('the singer's formant') [5]. The opera singers are able to reach these resonances, but without real physical image.

2. The mathematical model

2.1. Direct numerical method

The transfer matrix method using conic elements was used. The base of this method is wave equation of an acoustic duct with variable cross section *A(x)* and viscous losses (specific acoustic resistance r_s) [2]

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{1}{A} \cdot \frac{\partial A}{\partial x} \cdot \frac{\partial \phi}{\partial x} - \frac{1}{c_0^2} \cdot \left(\frac{\partial^2 \phi}{\partial t^2} + \frac{r_S}{\rho} \cdot \frac{\partial \phi}{\partial t} \right) = 0 . \tag{1}$$

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