Authors:
Peter Birkholz and Dietmar Jackèl

Affiliation:
Interactive Graphical Systems Group
Institute of Computer Sciences
University of Rostock
Germany

E-mail (Peter Birkholz):
piet@informatik.uni-rostock.de

Title:
Automatic fricative noise generation in the vocal tract based on aeroacoustic principles.

Abstract:

This study deals with the synthesis of voiced and voiceless fricatives in a one-dimensional time-domain simulation of the vocal tract system.
Fricative sounds are produced by forcing an airstream through a narrow constriction in the vocal tract above the glottis. In the vicinity of the constriction, the airstream becomes turbulent and the turbulent air motion constitutes a source of noise. The noise source is usually spatially distributed and has spectral properties that depend on several parameters, like the pressure drop across the constriction, the constriction size, the flow rate and the geometry downstream of the constriction (Shadle, 1991; Badin, 1989).
For the synthesis of fricatives with a discrete, one-dimensional tube model of the vocal tract, the distributed source must be approximated by one or more lumped sources. Depending on the circumstances, the lumped noise sources are monopole or dipole sources (Narayanan et al., 2000). A flow monopole source results from a net unsteady mass injection into the fluid region, like for instance directly at the exit of the supraglottal constriction. Flow dipole sources exist at obstacles in the path of an impinging jet, such as at the teeth during the production of /s/. For the production of voiced fricatives, an additional volume velocity source at the glottis is needed.
The challenge of this study is the development of a hybrid source model (comprising the glottal source as well as turbulent monopole and dipole sources), that automatically creates these different sources for fricatives at different places of articulation. Each lumped noise source has several parameters that determine the source type (monopole/dipole), the source spectrum and the amplitude. The aim is the determination of the relations between the vocal tract geometry, the flow conditions and the lumped source parameters. For the simulation of the voice source during the production of voiced fricatives we use the glottis model by Titze (1984).
As the first step, we have developed a computer program with which we can specify any vocal tract area function and the parameters of several noise sources interactively. The resulting output sound pressure spectra are calculated in real-time an can be compared to long-time average spectra of natural fricatives. In that way we can manually optimize the source parameters for the best spectral match between synthetic and natural fricatives. From the results of these examinations we derive the relations for the automatic source parameter determination in a time-domain simulation of the vocal tract.

References:

- P. Badin. Acoustics of voiceless fricatives: Production theory and data. *STL-QPSR*, 3:33--55, 1989.
- S. Narayanan and A. Alwan. Noise source models for fricative consonants. *IEEE Transactions on Speech and Audio Processing*, 8(2):328--344, 2000.
- C. H. Shadle. The effect of geometry on source mechanisms of fricative consonants. *Journal of Phonetics*, 19:409--424, 1991.
- I. R. Titze. Parameterization of the glottal area, glottal flow, and vocal fold contact area. *Journal of the Acoustical Society of America*, 75(2):570--580, 1984.