MODELLING OF VOICE PRODUCTION BASED ON BIOMECHANICS

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A mathematical model for numerical simulation of vowel phonation will be presented. The model offers possibilities for various vocological and logopedic/phoniatric applications.

Aeroelastic model of the airflow-excited self-sustained vocal fold oscillations was developed using the incompressible 1-D fluid flow theory for expressing the unsteady non-linear aerodynamic forces and the Hertz model of the contact (collision) forces between the vocal folds. The equations of motion for rotation and translation of the vocal fold-shaped vibrating element are based on an equivalent three lumped-mass dynamic system on two springs. The vectors for aerodynamic and collision forces define the excitation forces.

The output signal from the aeroelastic model of vocal fold vibration (either intraglottal pressure or derivative of the glottal airflow volume velocity) in time domain is used for excitation of the ***finite element (FE) model*** of the acoustic spaces of the human vocal tract obtained from magnetic resonance images. Transient analysis is used for simulation of phonation when the supraglottal spaces are excited at the position of the vocal folds. The output acoustic pressure signals from the simulations in time domain are converted into sound samples.

The modelling methods developed can be applied, for example, for studying the impact stress in the vocal fold tissue or the effects of various disorders (velopharyngeal insufficiency or clefting) or post operation states (e.g. after tonsillectomy) on human voice. Some effects can be evaluated perceptually by listening to the sounds generated by the output signals.

Close collaboration on biomechanics of voice has been recently carried out especially with Prof. A.-M. Laukkanen from the University of Tampere, Department of Speech Communication and Voice Research and with Prof. P. Alku from the Helsinki University of Technology, Laboratory of Acoustics and Audio Signal Processing, Prof. H. Herzel from the Humboldt University, and for a long time with Dr. Jan Švec, at present in the Department of Biomedical Engineering, University of Groningen, the Netherlands.

Some recent publications and presentations:

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