

Aerodynamic modelling

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The goal of this lecture is to provide a peek into “one of nature’s best guarded secrets” (Dowling and Ffowcs-Williams, “Sound and sources of sound”, John Wiley and Sons, New-York, 1983): flow-induced sound production, in the case of human speech. Due to the limited time and the complexity of the subject, this overview will be quite informal; (almost) no equations will be used but a list of selected references will be provided for those who are willing to go further than the present introduction.

The acoustics of voice sound production has been studied and modelled for years on the basis of source-filter theory. While quite efficient, especially for modelling vowels, one of the major drawbacks of such an approach is to overlook the interactions between the sound sources and the vocal tract. The importance of such an interaction is however crucial in many cases as this will be demonstrated during this lecture.

A brief introduction will first be made. Some basic principles of acoustics and fluid mechanics will be informally explained. A particular attention will be paid to the succession of physical assumptions that are classically made in speech research. Their meaning and the possible consequences will be discussed on the basis of practical examples.

As a basis for further discussion, the first part of this lecture will concentrate on the basics of “classical” acoustics for the vocal tract as described in Fant (“Acoustic theory of speech production”. The Hague, Netherlands: Mouton, 1960) for example. This will be illustrated by a practical example (vowel modelling) illustrating different degrees of approximations and their acoustical consequences. Much more problematic will be the analysis and the interpretation of the nature of the sound sources using such an approach. It will be shown, in particular, that while, in first approximation, voiced sounds and plosives can be accounted for, the same cannot be said about fricatives.

The second part of this lecture will therefore concentrate on an aeroacoustical approach to the production of speech sounds. This approach allows a systematic description of the acoustics of the vocal tract, of the flow-induced sound sources and also accounts for their interaction. The classical analogy of Lighthill (“On Sound Generated Aerodynamically: I. General theory,” Proceedings of the Royal Society of London, Series A, Vol. 211, pp. 564 587, 1952) will be first evoked while other formulations (vortex sound theory, Powell’s analogy ...) will be presented. The application to speech research will be demonstrated in the case of fricative sound production and also in the case of voiced sounds and plosives.