A Numerical Simulation of Sound Production in the Vocal Tract

March, 1993

Cheng-Xiang Lu

Numerical analysis methods, finite element method and finite volume method, were applied to investigate the acoustic characteristics in the vocal tract in speech production. Finite element methods were used to investigate the acoustic transmition characteristics of vocal tract. Using FE models of vocal tract during pronunciation of vowels, the sound field in the vocal tract was examined for various pressures and wall conditions. Furthermore, the relationships of cross-sectional shape of the vocal tract and the multi-modal propagation were discussed.

On the other hand, the shape of lips has been frequently simplified or omitted in considering the cross-sectional area function of vocal tract. The effects of actual lip shape on the sound radiation were examined. The differences of transfer functions were examined in detail for vowels /a/ and /i/ when the shape of the actual lips was simplified as a plane-radiation surface. The effects of lip shape on the distribution of sound pressures were also shown in the vocal tract and the surrounding space of the mouth opening.

Besides the transmission and radiation characteristics of the vocal tract, the sound sources were also discussed. Because of the inaccessibility and complexity of the laryngeal system, it is therefore necessary for detailed study by numerical methods. A dynamic three-dimensional finite volume model of the human larynx was constructed to obtain better knowledge of the transient characteristics of flow.

The viscous, incompressible Navier-Stokes equations were solved by finite volume method, and both of the pressure distributions at the glottis and the relationships between the glottal flow and the vocal fold vibration were illustrated. The dynamic, behavior of the glottal flow and the unsteady boundary layer effect above the glottis were also shown. Furthermore, a phase difference between the upper and lower edges of the vocal folds was adopted to construct a non-uniform glottis model for modeling the physiological reality. The results were compared to the uniform-glottis model and the theoretical model proposed by Ishizaka and Matsudaira respectively.