Fricative Synthesis Investigations Using the Transmission Line Matrix Method

A. Katsamanis and P. Maragos

Computer Vision, Speech Communication & Signal Processing Group

National Technical University of Athens, Greece

http://cvsp.cs.ntua.gr

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Goal

- Our goal is to build a computational model of speech production that will incorporate aeroacoustics in the vocal tract and account for significant physiological speech production properties.
  - Determine and model alternative sound sources.
    - Location, Spectrum, Intensity
  - Exploit multimodal articulatory data, i.e. Magnetic Resonance Images, Ultrasound Images, Electromagnetic Articulography Data of the vocal tract
  - Synthesize speech
    - Judge the relative importance of the involved factors and try to avoid the computational weight related to the unimportant ones.

Flow in the Vocal Tract

- We need to build a practical flow model
  - Similar to the model proposed by Sinder, Krane but extended to 3D.

Sinder, Speech Synthesis Using an Aeroacoustic Fricative Model

Krane, M., Aeroacoustic production of low-frequency unvoiced speech sounds

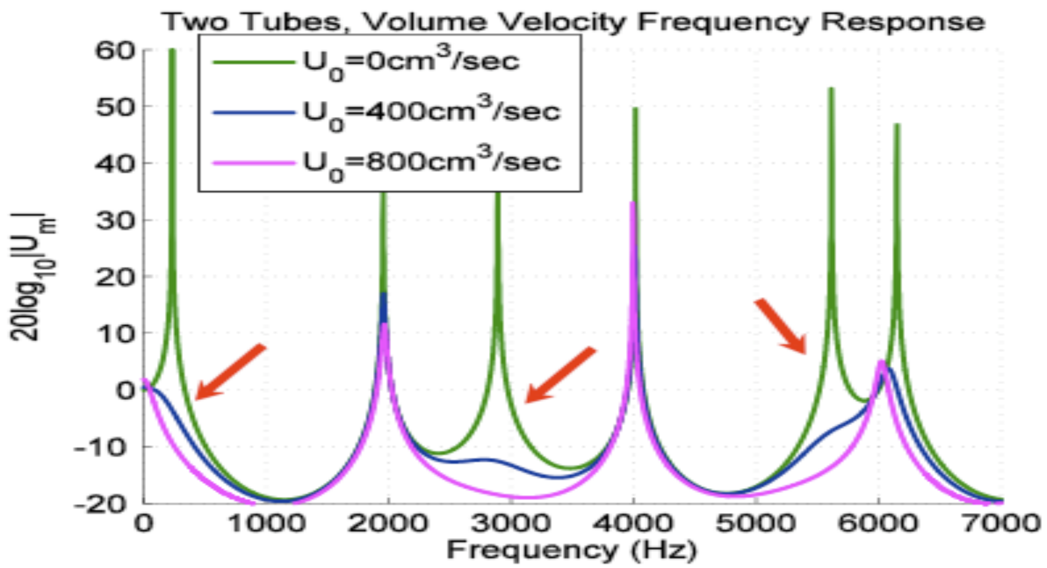
- Take into account fricative production specificities

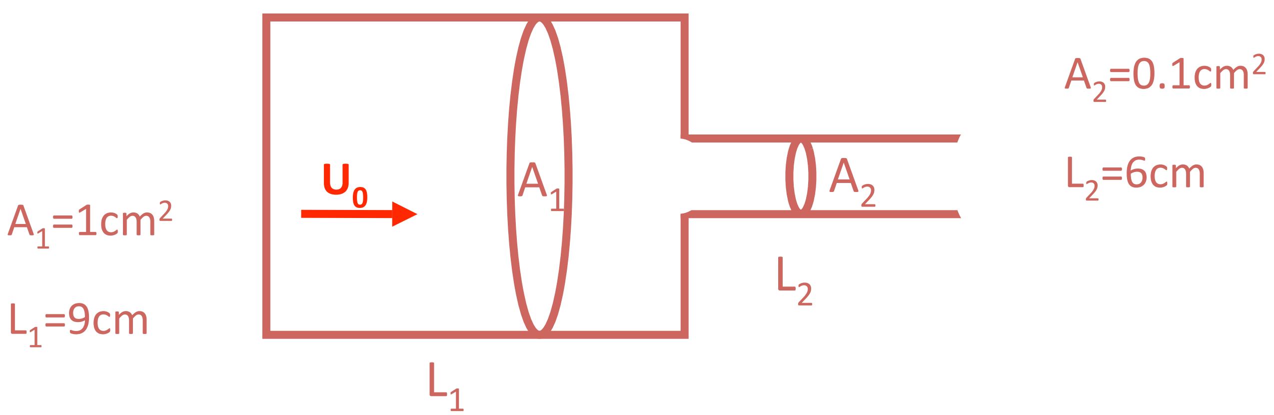
M.S. Howe, R.S. McGowan, Aeroacoustics of [s]

- Mean flow and acoustics in the vocal tract

P.O.A.L Davies, R.S. McGowan, C.H. Shadle, Practical Flow Duct Acoustics Applied to the Vocal Tract

A. Katsamanis et al., Investigations in Articulatory Synthesis





Vocal Tract Acoustics, Synthesis

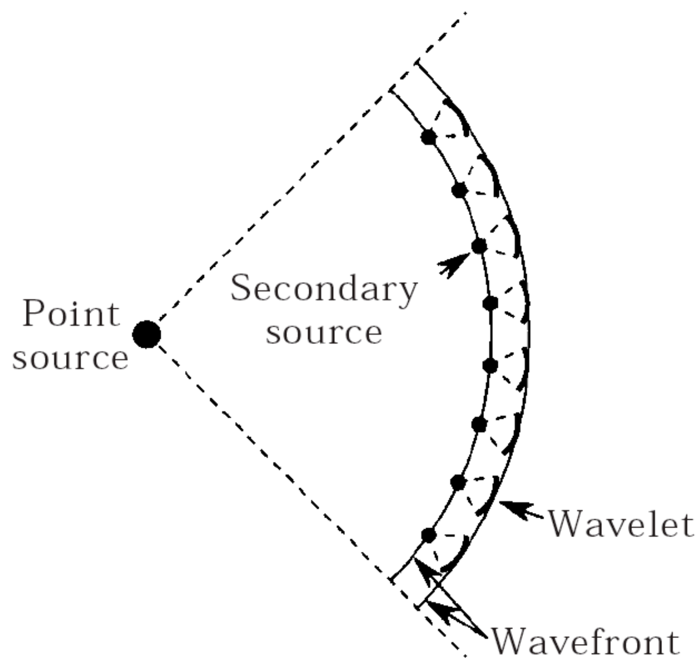
- We need a flexible/modular vocal tract acoustic simulator
  - Evaluate the differences between the simulations at increasing number of dimensions
- Computationally light but accurate
- Easily configurable and extendable
  - Account for sources, airflow
  - Complex geometry

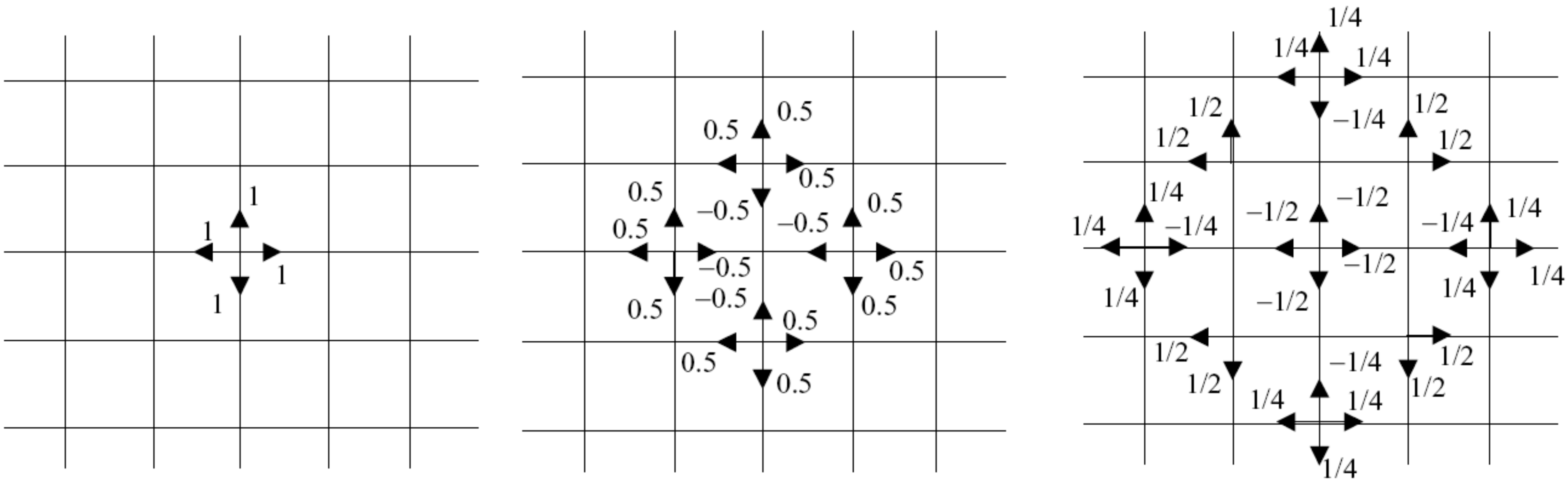
Transmission Line Matrix Method ?

S. El-Masri, X. Pelorson, P. Saguet, P. Badin, Development of the Transmission Line Matrix method in Acoustics

Transmission Line Matrix Method

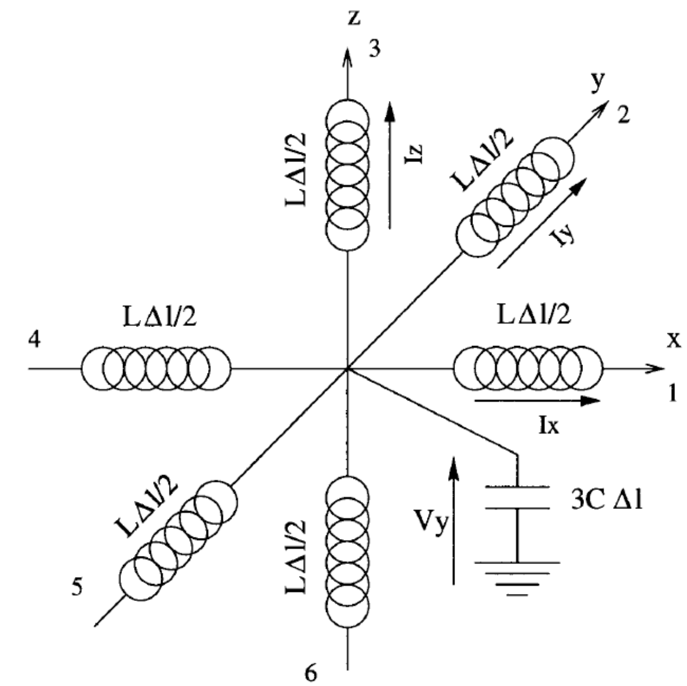
- Discrete Huygen’s model for wave propagation — Kagawa, 1998
- First introduced in Electromagnetics to estimate fields in complex waveguides — Christopoulos, 2006
- Has already been applied for acoustic





In 3D

- Time-domain implementation
- Cubic mesh



$$\begin{bmatrix} S_n \\ S_s \\ S_w \\ S_e \\ S_f \\ S_b \end{bmatrix} = \begin{bmatrix} -2 & 1 & 1 & 1 & 1 & 1 \\ 1 & -2 & 1 & 1 & 1 & 1 \\ 1 & 1 & -2 & 1 & 1 & 1 \\ 1 & 1 & 1 & -2 & 1 & 1 \\ 1 & 1 & 1 & 1 & -2 & 1 \\ 1 & 1 & 1 & 1 & 1 & -2 \end{bmatrix} \begin{bmatrix} I_n \\ I_s \\ I_w \\ I_e \\ I_f \\ I_b \end{bmatrix}$$

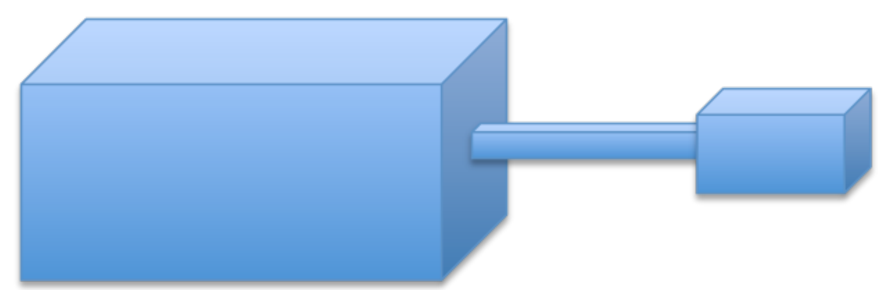
- Boundary Conditions
  - At rigid walls, the scattered pulse is equal to the incident one
  - To simulate infinite field, we have implemented absorbing boundary conditions

El-Masri et al.

Morente et al. Absorbing boundary conditions

Fricative Synthesis

- Simple 3-tube model to test feasibility
- Pressure noise source at a single point just in the beginning of the narrow tube
- White Gaussian Noise
- Spatial Resolution: 1mm
- Temporal Resolution: 10^{-6}
- MATLAB Implementation



Ongoing Work

- Model validation
  - Boundary conditions
  - Check with theoretically expected results for ducts
- Moving medium incorporation

O'Connor 2003, TLM Models of Waves in Moving Media

  - To consider mean airflow for acoustics
- Integration/parallel development of flow model
- Compare with 2D, 1D simulation