Formants from the Wave Equation

and

Recording Speech During MRI

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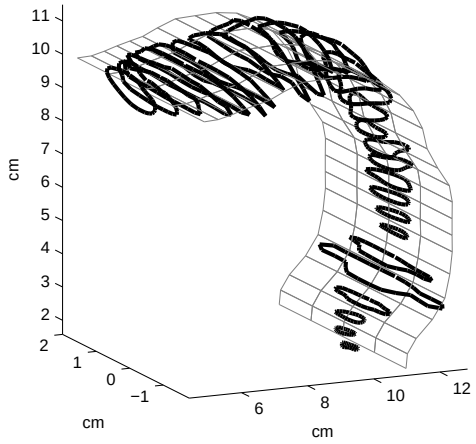
Goals

- The main goal is to simulate vowels based on a wave equation model.
- In the relatively near future, this simulator could be used to plan oral and maxillofacial surgery and to investigate abnormal anatomy.
- In the long term, we would like to predict the effects that medical operations will have on a patient’s speech production.

Background

$$\begin{cases} \Phi_{tt} = c^2 \Delta \Phi & \text{for } (\mathbf{r}, t) \in \Omega \times \mathbb{R}, \\ \Phi = 0 & \text{for } (\mathbf{r}, t) \in \Gamma_1 \times \mathbb{R}, \\ \frac{\partial \Phi}{\partial \nu} = 0 & \text{for } (\mathbf{r}, t) \in \Gamma_2 \times \mathbb{R}, \text{ and} \\ \Phi_t + c \frac{\partial \Phi}{\partial \nu} = 2 \sqrt{\frac{c}{\rho_0}} u & \text{for } (\mathbf{r}, t) \in \Gamma_3 \times \mathbb{R}, \end{cases}$$

(a)

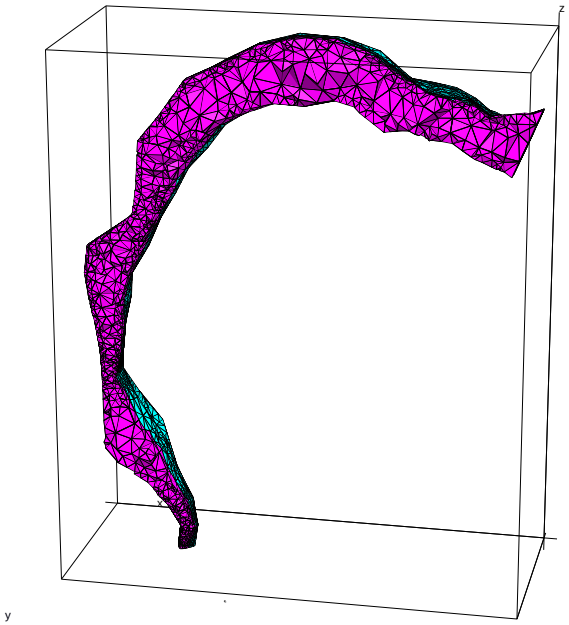


(b)

Figure 1: (a) The wave equation model and (b) a sample vowel geometry

- We need an extensive amount of additional accurate anatomic data and simultaneously recorded sound to validate the simulation results.

Mathematics: Finite Element Method in our project



- Our initial mesh had about 64000 tetrahedral elements.
- We do not aim to produce real time synthesis using the wave equation but we do expect to get reasonably close.
- The corresponding resonance problem, i.e., the computation of formants is not so heavy numerically.

Results: Pressure distributions

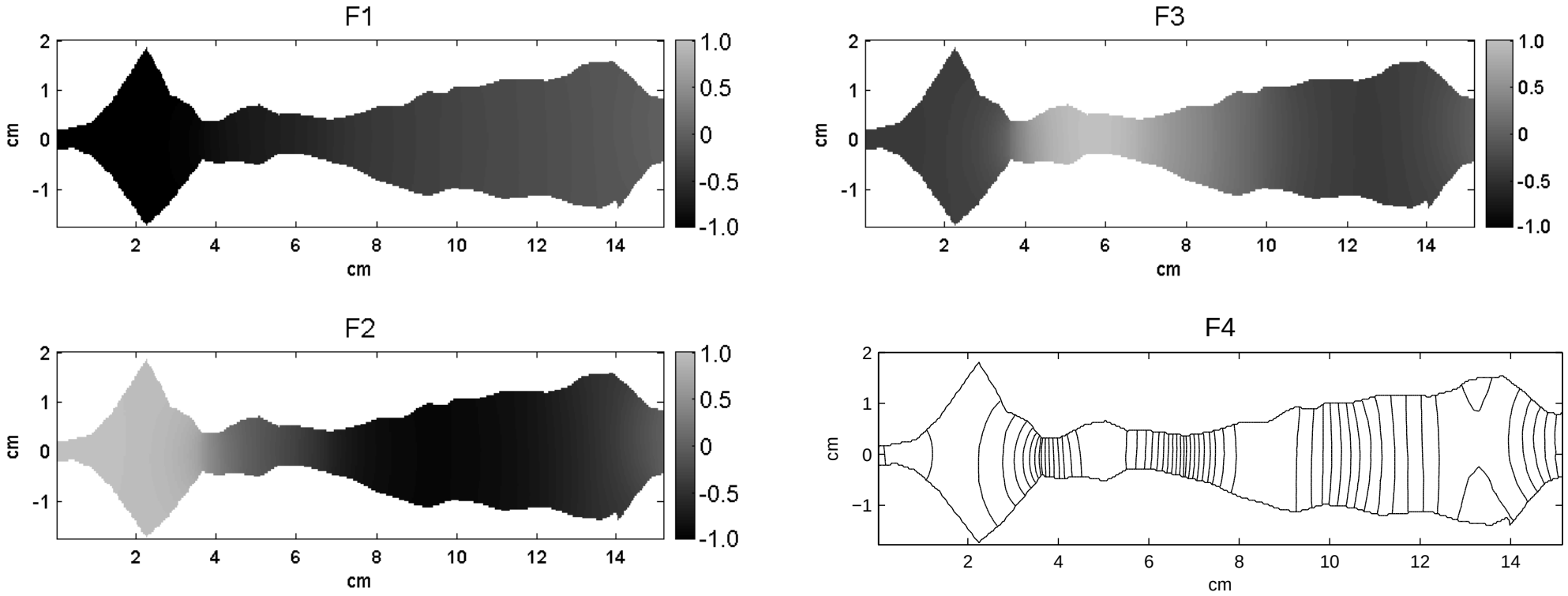


Figure 2: Four approximate eigenfunctions corresponding to the lowest eigenvalues ie. pressure distributions for formants 1-4. Glottis is on the left and mouth on the right.

Sound measurements: What would we like to get?

- The fundamental frequency F0, . . .
- F1, F2, F3 and, if possible, F4 . . .
- . . . and their bandwidths . . .
- . . . before, after and during the MR imaging sequence.
- Access to clean speech signal in real time.

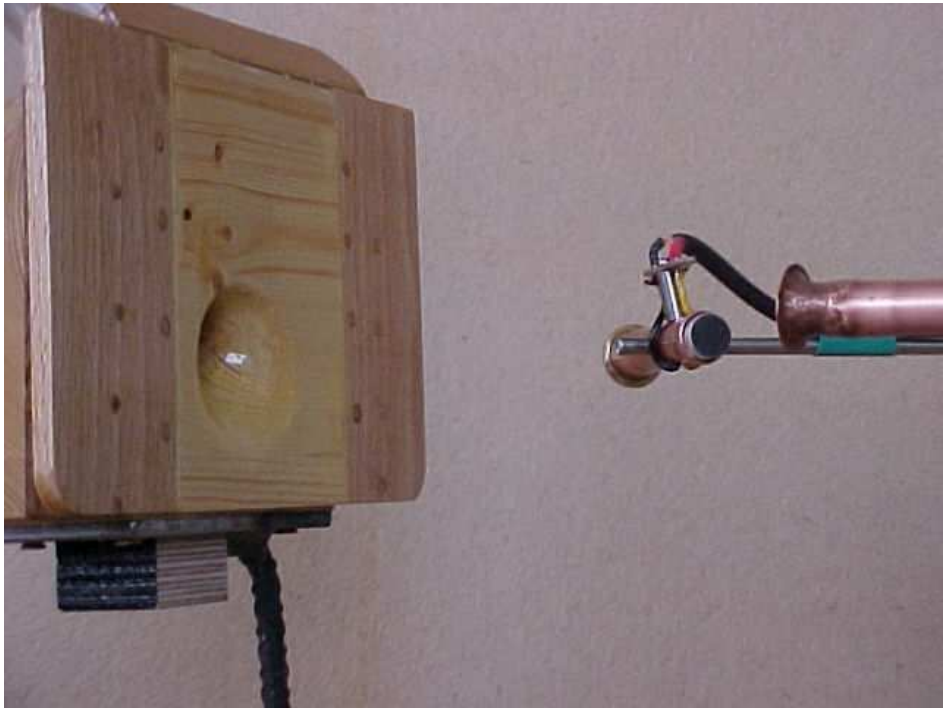
We would like to obtain large amounts of high quality, anatomically and phonetically relevant, simultaneous image and sound data.

Sound measurements: What’s the problem then?

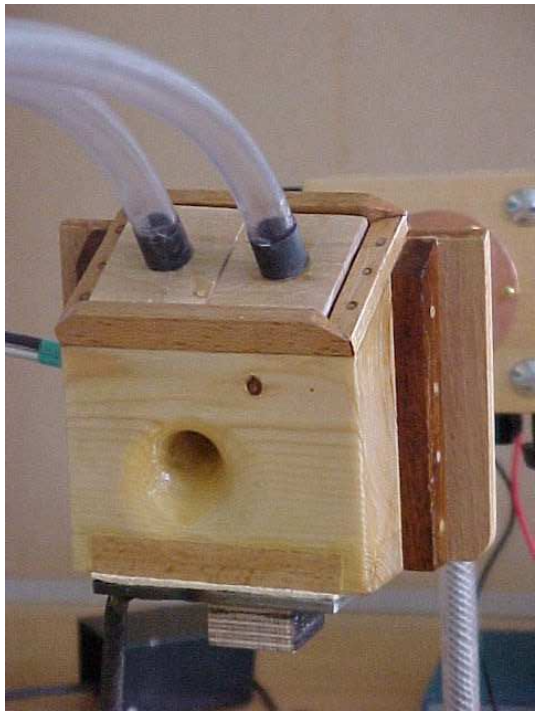
- No metal allowed inside the MRI main coil.
- No ferromagnetic material allowed inside the MRI room.
- All electronics in the MRI room have to be RF-shielded.
- Strong acoustic noise (over 90 dB SPL) present during the imaging sequence.

Sound collector

We have constructed a two channel sound collector for our system. One channel will sample the noise and the other the contaminated speech.



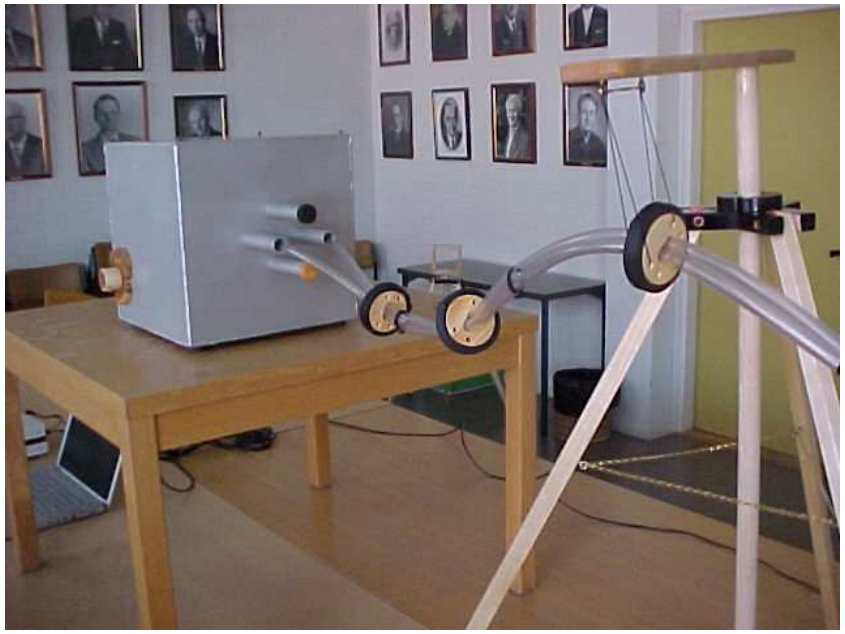
(a)



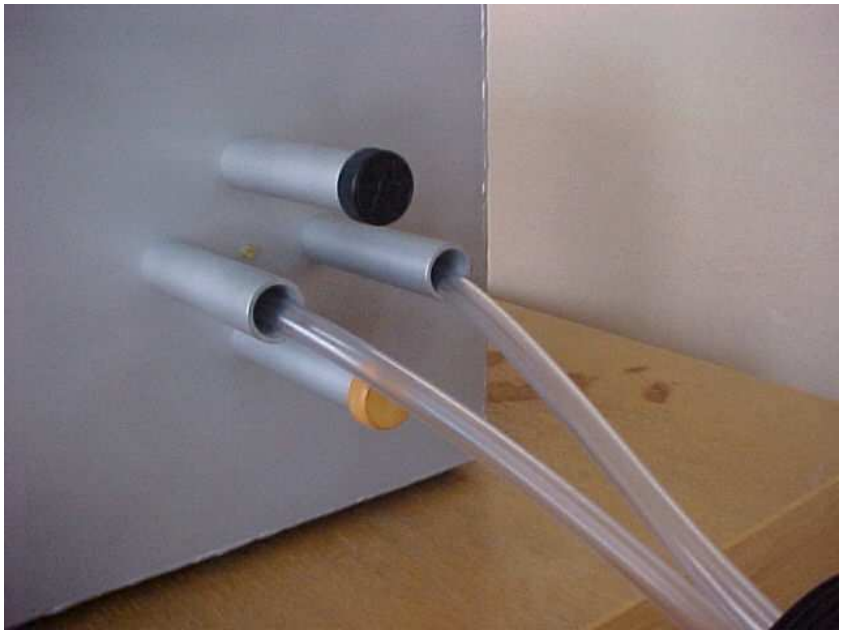
(b)

Figure 3: The sound collector from (a) below with the sound source and (b) above

Faraday cage



(a)



(b)

Figure 4: (a) The Faraday cage houses the microphones and (b) the acoustic waveguides enter the cage through electromagnetic waveguides

Tests: Does the noise cancellation work with acoustic components?

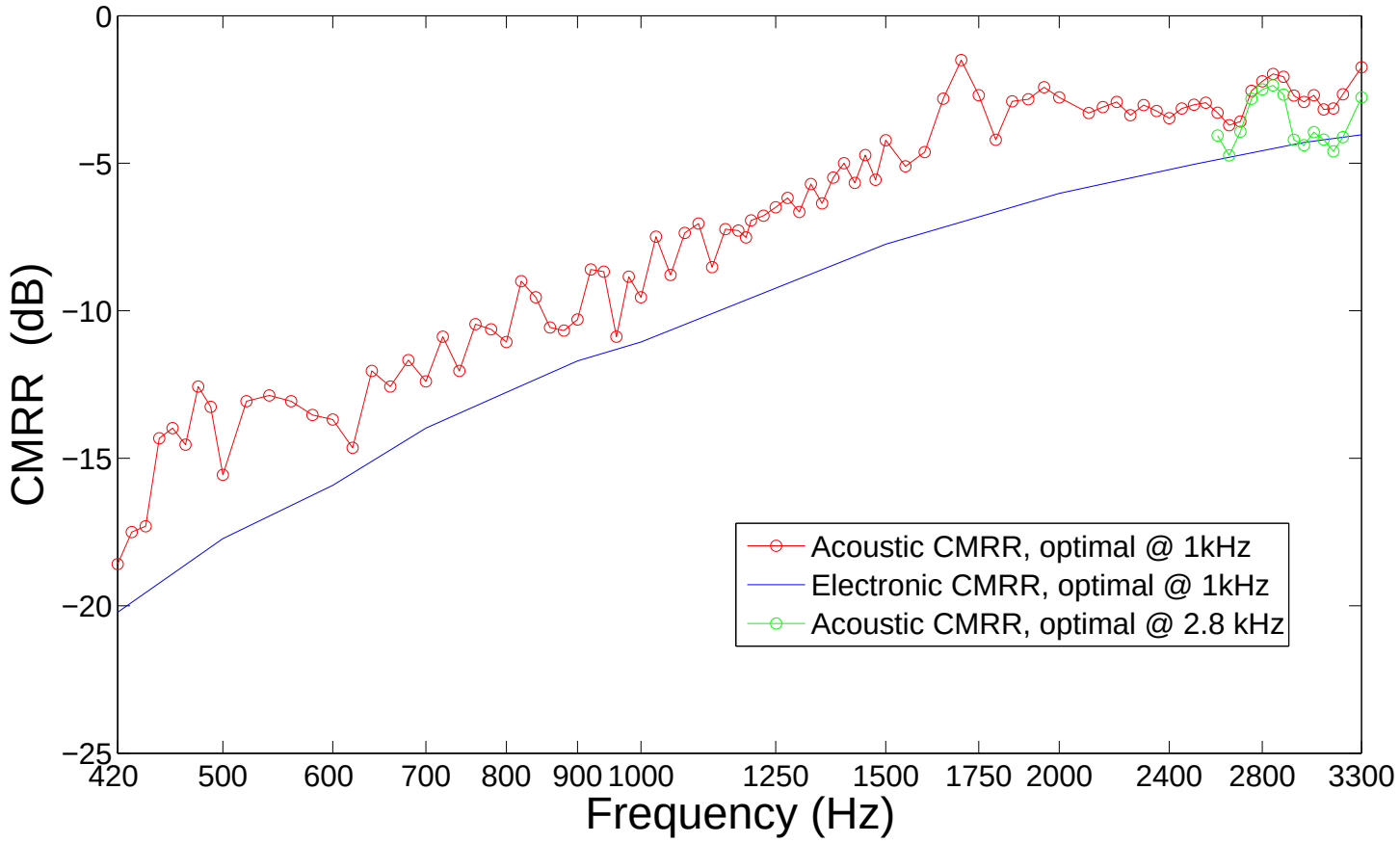


Figure 5: CMRR of the whole system excluding the sound collector

Thank you.

Questions, please?