Assignment 1
Speech Production

Introduction

This assignment is intended to reinforce some of the concepts introduced in the lectures on the acoustic theory of speech production. To do this, we will use a software facility called LAMINAR which was developed by the Spoken Language Systems group. Briefly, LAMINAR is an interactive system which allows a user to study the acoustic consequences of any vocal tract area function with different sources and losses.

You will use LAMINAR to investigate:

1. the distribution of pressure and volume velocity in the vocal tract, and the effect of source location on the poles and zeros of the vocal tract transfer function by way of a uniform acoustic tube,

2. the interaction of poles and zeros for the production of a consonant.

A brief introduction to the workings of LAMINAR is included with this lab. We recommend that you read this handout before coming to the lab, as it will reduce the amount of time it will take to become familiar with the system. The remainder of this lab assumes a working knowledge of LAMINAR. To start the lab simply enter the command:

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% start_lab1.cmd
```

Once in LAMINAR, you need to open the *lab.items* file containing the saved vocal tract configurations which you will use in this lab. You can open this file by pressing Alt+I or by selecting "*File→Load Items*" from the top menu bar.

During the lab, you may want to work out the numerical values of the poles and zeros and check your numbers against the results from LAMINAR. Make sure that you check the parameters of the vocal tract each time, since different parts of the lab may use different sampling rates, vocal tract lengths, or numbers of elements.

The following tasks (marked by **T**'s) should be completed during your lab session. The answers to the questions (marked by **Q**'s) should be handed in on the due date.

Part I: Uniform Vocal Tract

In this part of the lab we will investigate the relationship between the position and the type of the source and the poles and zeros of the vocal tract transfer function, and the distribution of pressure and volume velocity in the vocal tract. We will illustrate these concepts with a uniform vocal tract shape, which is appropriate for a neutral vowel.

T1: Enter LAMINAR and select the *uniform* vocal tract configuration. Remember that in order to select this configuration, you must position the mouse over the appropriate vocal tract in the *Tracts* window, and click the left mouse button once.

Enter a volume velocity source of magnitude 1.0 and a shunt loss of 0.1 in element 0 (by positioning the mouse in the area just above the 0 in the *Vocal Tract Area Function* window and clicking the left mouse button once) and a series loss of magnitude 0.1 in element 15. Synthesize this configuration, measuring the volume velocity output out of element 15. Remember that the currently selected vocal tract may be synthesized by positioning the mouse pointer in the *Outputs* window, clicking the right mouse button once, and then selecting the *Create Output* option in the pop-up menu. You may want to change the name of the output to something informative, like *"uniform U@0 u@15"* (for: uniform tube, volume velocity source at element 0, volume velocity output measured at element 15), so that you can easily compare the output from different configurations. Observe and measure the locations of the poles of the resulting frequency response displayed in the *Spectrum* window. Change the losses associated with the source and radiation and see how they affect the rate of decay of the impulse response and the bandwidth of the resonances.

Q1: Does the location of the poles agree with predictions based on acoustic theory? If not, what could have caused the discrepancies?

T2: Remove the series radiation loss at the lips. Synthesize this vocal tract configuration, except this time you should observe the volume velocity out of element 10. Also observe the pressure at element 9.

Q2: Compare the output at element 10 to the one you obtained in **T1** and explain the differences.

T3: Replace the volume velocity source at element 0 with one at element 10, and re-synthesize the configuration. Note that the frequency response shows zeros as well as poles. Measure the locations of the zeros.

Q3: Explain the values of the zeros from the position of the source.

T4: Replace the volume velocity source at element 10 with a pressure source and re-synthesize the configuration. Measure the locations of the zeros.

> **BONUS:** What causes the differences between this configuration and the previous one? Why do some of the zeros have lower amplitude than others?

Part II: Vowel Production

T5: According to perturbation theory, rounding the lips (which causes the vocal tract to lengthen slightly and the open end to narrow) will lower all formant frequencies (i.e., pole frequencies). We will investigate this theory.

Select the vocal tract configuration for /i/ and synthesize the configuration. Note the position of the formants.

A fronted /u/, as in the last syllable in the word "institute" (or the French "rue" or the German "grün"), is articulated similarly to an /i/, but with rounded lips. Simulate lip-rounding by decreasing the area of the acoustic tube at the "lips." Synthesize the new configuration, and overlay the /ü/ spectrum on the /i/ spectrum.

> **Q4:** Which of the lowest three formants are most affected by "rounding"? Why?

Part III: Consonant Production

In this part of the lab, we will illustrate several properties in the production of consonants with the velar stop as an example.

T6: Select the /g/ vocal tract shape. (Note that we have inserted some losses at the constriction.) Determine the pole locations by placing a volume velocity source in element 0 and measure the output. Notice the second and third formants are very close, creating a prominent and compact spectral peak. This is a property of the velar articulation.

> **Q5:** Determine which cavity is affiliated with each of the peaks in the spectrum.

T7: To determine the zero locations, replace this volume velocity source with a pressure source just in front of the constriction (at element 12) and measure the output again.

> **Q6:** Why has the amplitude of the third formant decreased?

Q7: In addition to the zeros introduced by the back cavity, you will observe an additional free zero, between 2 and 3 kHz. Explain its origin.

T8: Widen the constriction for the /g/ configuration, and repeat **T6** and **T7**.

Q8: What are the effects of widening the constriction on the poles and zeros of the system?

T9: Select the /s/ configuration. Place a pressure source one element to the right of the end of the constriction.

BONUS: Try to explain the origin of all the poles and zeros.