Assignment 1 Information
An Introduction to LAMINAR

The LAMINAR (Line Analog Models for Interactive Articulation Research) facility is capable of synthesizing speech from different vocal tract configurations. The system is based on an enhanced version of the Kelly-Lochbaum acoustic-tube model, and computes impulse responses of static vocal tract configurations. By allowing the user to interactively alter vocal tract areas, losses and sources, LAMINAR provides a useful mechanism for studying the acoustic theory of speech production.

As illustrated in Figure 1, there are several displays available in LAMINAR. Each of these is used in an interactive manner by the user to create and observe synthesized waveforms. The following sections provide information necessary to be able to use the system effectively. You may also wish to refer to the Workstation Introduction handout which provides general information about using the Dell Linux workstations.

1 Vocal Tracts

All investigations in LAMINAR center around the vocal tract. Currently, the vocal tract is modeled as a sequence of N elements, each of length x. The vocal tract length L, is thus Nx. Each element has an area A, and may also include some kind of loss or source. In LAMINAR, a list of all vocal tracts is kept in the *Tracts* window. The vocal tract area function of a particular tract may be displayed by selecting a tract in this window. This is done by positioning the mouse pointer over the tract of interest, and clicking the left mouse button once. The name of the currently selected tract is always highlighted in the *Tracts* window.

1.1 Vocal Tract Commands

In addition to selecting an existing tract, a user can also create a new tract, make a copy of, alter, or delete a selected tract. Any of these four operations may be invoked by positioning the mouse pointer in the *Tracts* window, clicking the right mouse button, and then selecting the appropriate command in the resulting pop-up menu.
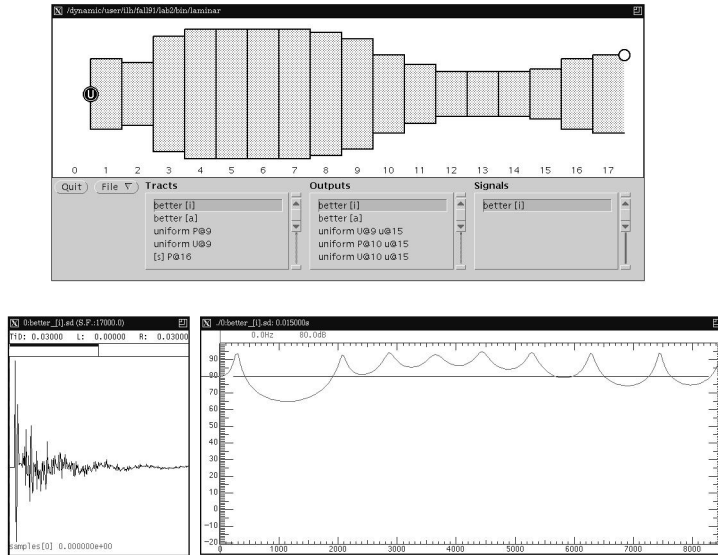
Figure 1: LAMINAR Displays

If the *Create Vocal Tract* command is selected a *Create Vocal Tract* window will appear containing default values for the vocal tract length, the number of sections in the vocal tract, the sampling rate used for synthesis, as well as the name of the vocal tract itself. Any of these values may be changed by the user. To change a parameter value, position the mouse pointer over the appropriate value, click the left mouse button once, type the new value, and press the *return* key. Note that there is a relationship between the vocal tract length L, number of sections N, and sampling rate F_s, $L = \dfrac{Nc}{2F_s}$, where c is the speed of sound in air, which defaults to be 35,400 cm/sec.

The *Copy Vocal Tract* command will create a duplicate version of the currently selected vocal tract for further editing. This new tract will become the currently selected vocal tract.

The *Alter Vocal Tract* command allows the user to change the name, sampling-rate, and vocal tract length of the currently selected vocal tract.

The *Delete Vocal Tract* command will remove the currently selected vocal tract from the *Tracts* window.

1.2 Modifying a Vocal Tract Configuration

Once a vocal tract has been created or selected, it will be displayed in the *Vocal Tract Area Function* window. It is then possible to modify the areas of some of the elements, or add losses or sources along the tract, or change the network of connections among the elements in the vocal tract. By positioning the mouse pointer over a particular element in the *Vocal Tract Area Function* window, and clicking the
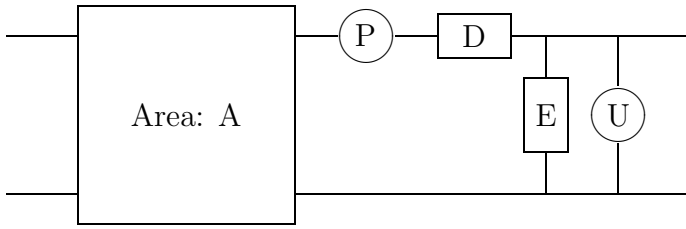
Figure 2: An element of the vocal tract

left mouse button once, the user will create an *Alter Element* window which contains the current parameter values for that particular element. Any of these values may be changed by the user in the manner described previously.

It is important to note that all losses and sources occur on the *right* side of an element as illustrated in Figure 2. This point becomes obvious in the *Vocal Tract Area Function* window, since the position of all losses and sources are superimposed on the vocal tract area function. This positioning introduces a slight problem at the beginning (left end) of the vocal tract where one would like to insert a current source with some shunt loss. Currently in LAMINAR this is accomplished by having an element 0 which has an area of 0 (and thus an infinite impedance) to the left of the first element. In order to insert a volume velocity or shunt loss before the first element, it is element 0 which must be edited. This element can be edited by clicking the left mouse button in the region above the 0, to the left of the first element. Make sure that the area of this element remains 0.

Another issue which arises is the value of the losses and sources. Currently, since LAMINAR computes only the impulse responses, the value of a pressure or volume-velocity source determines the magnitude of the impulse. Thus this value is only relevant if multiple sources are used. The value of the loss however, relates directly to the characteristic impedances of the tubes on either side of the loss. Specifically, the series loss factor $D = \dfrac{R}{Z_a + Z_b}$ where Z_a and Z_b are the characteristic impedances of the adjacent elements, $Z = \dfrac{\rho c}{A}$, and R is the series resistance of the lossy element. The shunt loss factor $E = \dfrac{G}{Y_a + Y_b}$ where Y_a and Y_b are the characteristic admittances of the tubes, and G is the shunt conductance of the lossy element. Notice that currently all losses are frequency independent and thus real.

A final point to be made here is that since element 0 has an infinite impedance, there is no point in adding a pressure source or a series loss since they are effectively disconnected from the rest of the circuit. Further, at the point of radiation the area is assumed to be infinite thus acting like a short circuit and making any shunt loss at the last element in the vocal tract irrelevant.

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2 Vocal Tract Outputs

Once a complete vocal tract shape has been established, it is possible to synthesize the impulse response of the vocal tract to any sources in the vocal tract. All synthetic outputs are stored in the *Outputs* window. The waveform and spectrum[1] of a particular output may be displayed by selecting an output in this window. As was the case for vocal tracts, an output is selected by positioning the mouse pointer over the output and clicking the left mouse button once. The name of the currently selected output is always highlighted in the *Outputs* window.

2.1 Vocal Tract Output Commands

In addition to selecting an existing output, a user can also create a new output, alter, or delete a selected output. Any of these three operations may be invoked by positioning the mouse pointer in the *Outputs* window, clicking the right mouse button, and then selecting the appropriate command in the resulting pop-up menu.

If the *Create Output* command is selected a *Create Output* window will appear allowing the user to identify the element whose output they wish to measure, the type of measurement, the systhesis duration, as well as the name of the output itself. In order to be able to distinguish between different outputs, it is often useful to identify the source location and type, as well as the measurement location and type in the output name. For example *"uniform U@0, u@15"* might indicate that the output corresponds to the impulse response of a uniform tube with a volume velocity source at element 0, with the volume velocity being measured at the output of element 15.

The *Alter Output* command allows the user to modify the name of the currently selected output, while the *Delete Output* command removes the currently selected output from the *Outputs* window.

2.2 Output Signals

A synthetic output corresponds to vocal tract impulse response. It is possible to create a synthetic signal by convolving this impulse response with either a periodic or random source. All signals are stored in the *Signals* window. A selected signal is played. A user may also create a new signal, or alter, or delete a selected signal. A menu of these three commands is created by positioning the mouse pointer in the *Signals* window, and clicking the right mouse button. If the *Create Signal* command is selected a *Create Signal* menu will appear allowing the user to select a name, signal duration, as well as source excitation type and period (in the case of a periodic source).

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[1]These displays use the WAVES+ software, which is described in the "An Introduction to Using WAVES+" handout.

3   Loading, Saving, and Killing Parameters

LAMINAR has the capability to load, save, or clear vocal tract shapes, outputs, and signals. These commands can be selected from a menu invoked by positioning the mouse pointer over the *File* button and clicking the right mouse button. The *Load Items* command prompts the user for a filename. The loaded items are added to the existing tracts, outputs, and signals. The *Save Items* command saves all existing tracts, outputs, and signals to a file specified by the user. The *Clear Items* commands clears all items in the *Tracts*, *Outputs*, and *Signals* windows.

4   Getting Started

To begin the lab you will need an *items* file which contains 5 default acoustic tube configurations. A copy of this file will be located in the lab1 subdirectory of your home directory. It is called *lab.items*. To load this file, push down on the left mouse button within the File button in LAMINAR and select the Load Items option. This will pop up a window in which you must select or type the name of the file you want.