COLEA:

A MATLAB software tool for speech analysis

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Installation Instructions

System Requirements

- IBM compatible PC running Windows 95
- MATLAB ver. 5.x and MATLAB's Signal Processing Toolbox
- Sound Card (any soundcard that runs in Windows, e.g., SoundBlaster)
- 700 Kbytes of disk space

Installation steps

♦ PC/Win95

After downloading the file 'colea.zip' to your PC, create a new directory, and pkunzip the file in that directory, i.e., type: **pkunzip colea.zip**

♦ Unix

After downloading the file 'colea.tar', type: **tar xvf colea.tar** to un-tar the file. This will automatically create a new directory called 'colea'.

Getting Started

After getting into MATLAB, go into the colea directory, i.e., type **cd \colea**. After typing **colea** you will see a file dialog window, from which you can select a file. COLEA can process several file formats by reading the extension of the file (e.g., .WAV, .VOC, etc). The file extension is very important because each file format has different header information. COLEA knows the file's sampling frequency, the number of samples, etc., by reading the header. Several file formats are currently supported:

- .**WAV** - Microsoft Windows audio files
- .**WAV** – NIST's SPHERE format - new TIMIT format
- .**ILS**
- .**ADF** - CSRE software package format
- .**ADC** – old TIMIT database format
- .**VOC** - Creative Lab's format

If a file does not have any of the above extensions, then COLEA will convert the file to .ILS format. In that case, you will be asked to enter the sampling frequency as well as the size of the header in bytes. After entering the sampling frequency, hit the <Enter> key.

Another way of getting into COLEA is by typing:

colea filename.xxx

where filename.xxx is the name of the speech file.

A Guided Tour

An example is given below that will help illustrate some of COLEA's features. In the colea directory, type: **colea had.ils** and you will see the display shown in Figure 1.

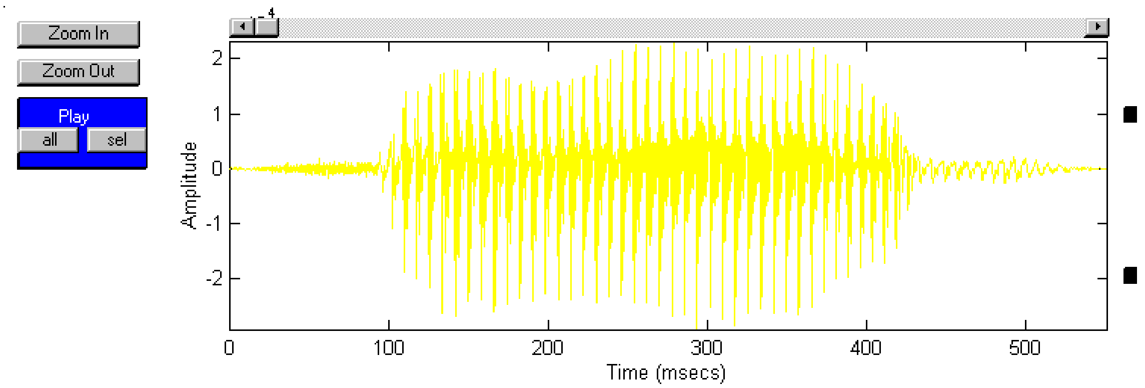
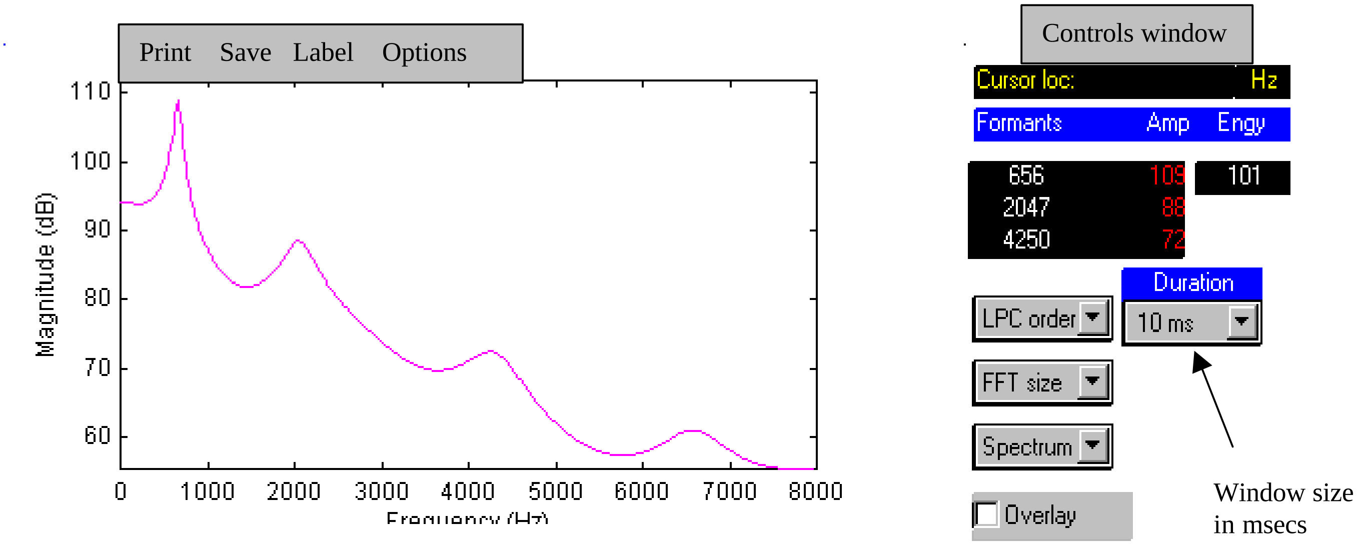


Figure 1 The main COLEA window showing the time waveform of the word 'had'.

What you see is the time waveform of the word 'had' (sampled at 16 kHz). Now, point the cursor somewhere near the 200 msecs region in the waveform, and then click the **left** mouse button. Immediately after that you will see the display shown in Figure 2



Cursor loc: Hz

Formants	Amp	Engy
656	109	101
2047	88	
4250	72	

Duration: 10 ms

Window size in msecs

Figure 2 (Left panel) The LPC spectrum of the vowel /ae/ in "had". (Right panel) The controls window provides information about the first three formant frequencies (Hz) , formant amplitudes (in dB), energy (Eng) of the windowed segment (in dB), as well as the window size (in msecs) used in LPC (or FFT) analysis.

appearing at the bottom of the screen. This spectrum was obtained by performing a 12-pole LPC analysis on the 10-msec speech segment taken *right of the cursor*. So, when you click anywhere on the waveform using the left mouse button, the program takes a 10-msec window of the speech segment immediately after the cursor line, and performs LPC analysis. You may change the size of the window, using the *Duration* pull-down option shown in the controls window (Fig. 2, right panel).

Controls window options

Among other things, the controls window in Figure 2 displays estimates of the formant frequencies and formant amplitudes (in dB). The formant frequencies are computed by peak-picking the LPC spectrum. To get accurate estimates of the formant frequencies, one needs to choose the LPC order properly depending on the sampling frequency. Although 12-pole LPC analysis is typically adequate for telephone speech, it is not adequate for speech recorded at sampling frequencies of 16 kHz or above. In the example above (Fig. 2) the LPC order was 12, and the third formant (F3) had a value of F3=4250 Hz, which is suspiciously high for a third formant (for an adult male speaker). Increasing the LPC order to 18 will yield a better estimate of the second and third formants for this example. The LPC order can be increased using the ‘LPC order’ pull-down option in the controls window (Fig. 2).

If you want to see the FFT spectrum instead of the LPC spectrum, you can do that by selecting ‘FFT’ in the ‘Spectrum’ pull-down option in the controls window. After selecting the FFT spectrum, you have a choice on the size of the FFT using the ‘FFT size’ option in the controls window.

If you want to see the FFT spectrum overlaid on top of the LPC spectrum, then click on the ‘Overlay’ box in the controls window. The ‘Overlay’ box in Figure 2 can also be used for overlaying several spectra for comparative purposes. When checking the ‘Overlay’ box the current LPC display (Figure 2) freezes, and any subsequent spectra are overlaid on top of previous displays. To try out this option, check the ‘Overlay’ box and click with the left mouse button somewhere in the waveform. In order to get back to the single-display-at-a-time mode, check the ‘Overlay’ box one more time.

When you click anywhere in the LPC spectrum window using the left mouse button, you will see the cursor location (Cursor loc) in Hz in the controls window.

LPC Spectrum window

There are four pull-down menus in the LPC spectrum window (Fig. 2): **Print | Save | Label | Options**

The Print and Save options are used for printing or saving the spectra in the LPC window in several formats including postscript, windows metafile, etc.

The **Label** menu is used for adding text or legends on the figure or deleting existing text in the figure. To add text on the figure, select ‘Add text’ and then you will see a small text window, in which you type the text you want to add in the figure. After typing the text, hit the <Enter> key, and then point the cross-line cursor at the location in the LPC window where you want to insert the text, and click the left mouse button. To delete the last text inserted in the figure, use the ‘Delete text’ option.

The **Options** menu has the following sub-menus: -*Set frequency range*
-*LPC analysis* -..
-*FFT analysis* -..

The ‘*Set Frequency Range*’ sub-menu is used for setting the frequency range. In the example above (Fig. 2) the frequency range was 0-8000 Hz, that is, it was 0-Fs/2, where Fs is the sampling frequency. If you want to see the spectrum in the range, say, 0- 5kHz, then you may do so using the ‘Set frequency range’ sub-menu.

The ‘LP*C analysis*’ sub-menu is for setting a few options in LPC analysis such as using (or not using) a pre-emphasis FIR filter of the form $H(z) = 1 - 0.97z^{-1}$, and using

Hamming or rectangular window. The ‘FFT analysis’ menu has the same options, in addition to displaying the spectrum using lines or in picket-like form.

As a means of example, Figure 3 shows how some of the above options were utilized. The window duration was set to 30 msecs, the ‘Overlay’ box was checked on, the frequency range was set to 0-5 kHz, and the ‘Label’ pull-down menu was used to insert three labels for the three formants - F1, F2 and F3 (to create the left arrows, the LaTex command \leftarrow was used).

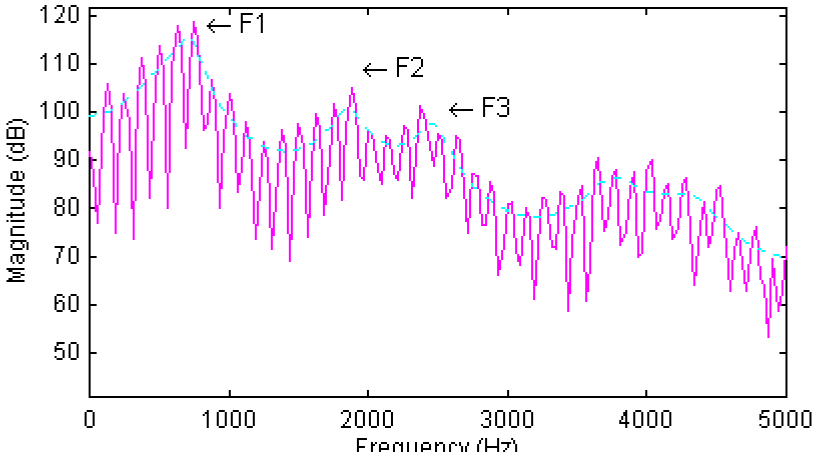


Figure 3 The FFT and LPC spectrum of the vowel /ae/.

Buttons in the main COLEA window

A description is given next for the buttons shown in the main COLEA window (Figure 1).

Zoom in

Used for zooming in to a selected region of the waveform. In order to select a region, you need to mark the beginning of the region and the end of the region. The beginning is marked by clicking the left mouse button and the end is marked by using the right mouse button. After you mark the region hit the 'Zoom in' button.

Zoom Out

Used for zooming out of a zoomed region.

Play

- **All** - Plays back the whole speech file, or the speech segment contained in a zoomed display.
- **Sel** - Plays back only the **Sel**ected region (contained between the red solid line and the purple dashed line). A region can be selected using the left and mouse buttons (see *Zoomed In)*

Pull-Down menus

On the top of the main COLEA window you will see the following pull-down menus labeled as:

- **File**
  - -*Load and Stack*
  - -*Load and replace*
  - -*Save whole file*
  - -*Save selected region*
  - -*Insert file at cursor*
  - -*File Utility*
  - -*Print Landscape*
  - -*Print Portrait*
  - -*Print to File*
  - -*Exit*
- **Edit**
  - -*Cut*
  - -*Copy*
  - -*Paste*
  - -*Zero segment*

-*Amplify or attenuate segment*
-*Insert silence at cursor*

- **Display**
  -*Time waveform*
  -*Spectrogram*
  -*Single window*
  -*Energy plot*
  -*F0 contour*
  -*Formant track*
  -*Power Spectral Density*
  -*Preferences*
- **Record**
- **Tools**
  -*Add white noise*
  -*Add noise from file*
  -*Convert to SCN noise*
  -*Filter tool*
  -*Sinewave generator*
  -*Label tool*
  -*Comparison tool*
  -*Volume control*

A brief explanation of some of these options is given next.

FILE

Load and Stack

This option in the FILE menu is used for displaying two files (see Figure 4). The COLEA window is split in to two smaller windows. The top window displays the new speech file, while the bottom window displays the old speech file. The top window can be selected by clicking, using the right mouse button, the top waveform. Likewise, the bottom window can be selected by clicking, using the right mouse button, the bottom waveform. A small yellow box appears next to the selected window, and this is how you know which of the two windows is active. So, if for example you want to listen to the top waveform, just click anywhere in the top waveform using the right mouse button, and then click on the 'Play' button. In order to switch to a single-window display, choose from the DISPLAY menu, *Single window*.

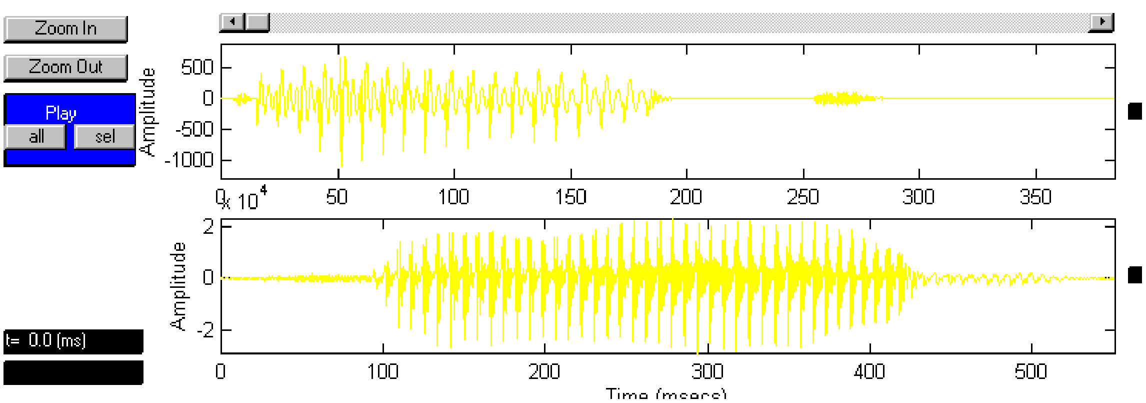


Figure 4 The '*Load and stack*' option from the FILE menu can be used to display two speech files.

Load and replace

The '*Load and replace'* option in the FILE menu loads a new file which replaces the old file. The new speech file is displayed in single-window mode, as in Fig. 1.

Save selected region

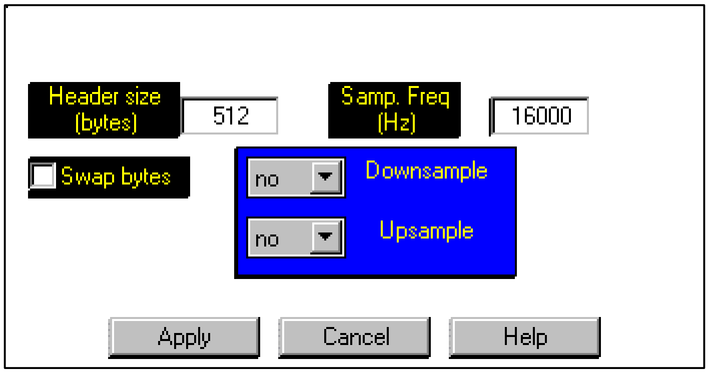
This option allows you to save a selected speech segment (the selection is made using the left and right mouse buttons) to a file. It is very important that the given filename has the same file extension as the original file.

Insert file at cursor

The '*Insert file at cursor'* option allows you to insert another file at a cursor location specified with the left mouse button.

File Utility

The '*File Utility*' (shown to the right) is used for upsampling or downsampling the speech signal, for swapping bytes or for changing the sampling frequency and the size of the header.



Header size (bytes) 512

Samp. Freq (Hz) 16000

□ Swap bytes

no Downsample

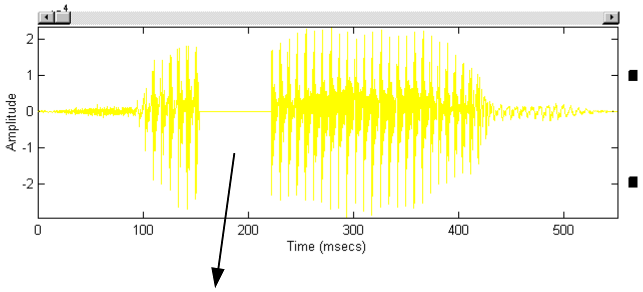
no Upsample

EDIT

The EDIT menu allows you to cut, copy as well as paste selected segments of the time waveform. Before using this menu you need to select first, using the left and right mouse buttons, the speech segment that you would like cut or copied. To paste a selected segment, click the left mouse button at the location where you want to insert the new segment, and then choose the “paste” option from the EDIT menu.

Zero segment

The ‘*Zero segment*’ option is used for zeroing a selected speech segment, as shown in the figure on the right.



Zeroed segment

Amplify/Attenuate

This option is used for amplifying or attenuating selected speech segments by a factor of 2 or ½ respectively.

Insert silence at cursor

The ‘*Insert silence at cursor*’ option is used for inserting X msecs of silence at the cursor, where X is the number of msecs specified by the user.

DISPLAY

Spectrogram

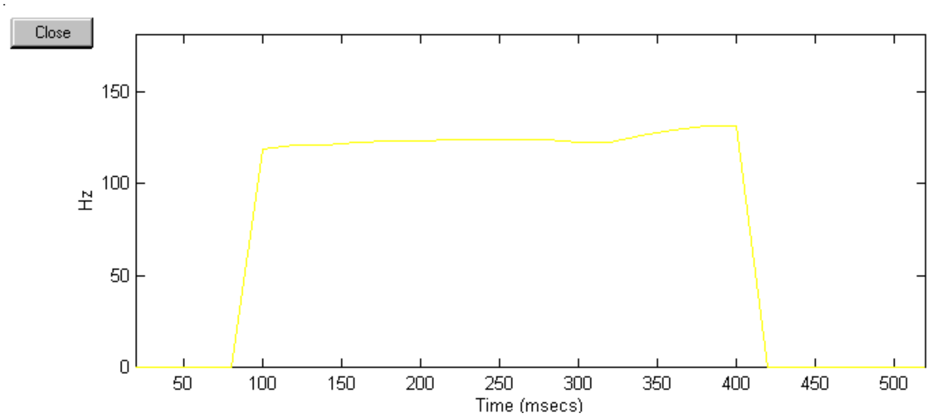
This option displays the spectrogram (in color or in gray scale) of the speech signal. The default frequency range for spectrogram display is 0-5 kHz. To display full range, i.e., from 0-Fs/2, use the ‘Full range’ option from the Spectrogram submenu. To switch back to the time waveform select the ‘*Time waveform*’ option from the DISPLAY menu.

Energy plot

This option is used for displaying the energy contour computed every 20-msec intervals, and expressed in dB.

F0 contour (pitch contour)

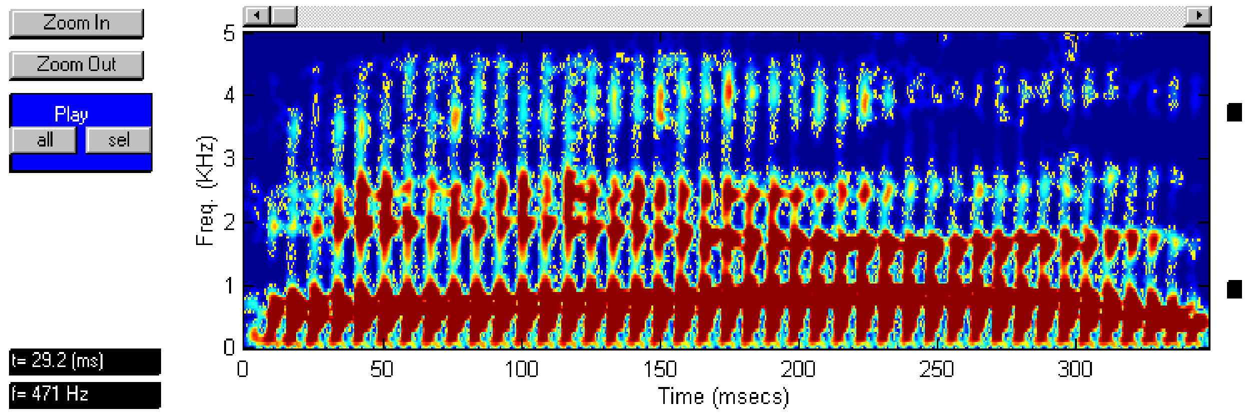
The pitch contour can be computed using either the autocorrelation method or the cepstrum method [1][2]. A simplified implementation of the cepstrum approach is used here. In the original method proposed by Noll [2], a great number of rules was used to preserve pitch continuity or avoid pitch doubling errors. No such rules are used in the present implementation. The pitch contour for the example file ‘had.ils’ is shown in the figure on the right. The average F0 is displayed in the title of the Figure window.



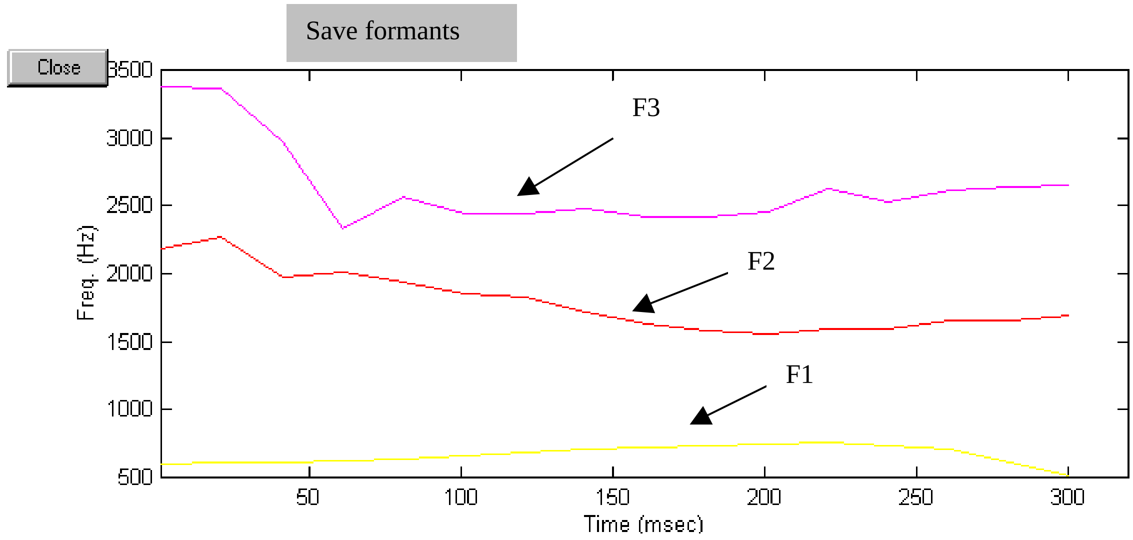
The user has the option of saving the F0 values in a file, by clicking on the ‘*Save pitch values*’ option next to the ‘Help’ menu of the pitch contour window.

Formant track

This option displays the formant track of a selected speech segment or the formant track of the whole speech file. Formant frequencies (F1, F2 and F3) are computed by solving for the roots of the LPC polynomial [3]. Heuristic rules are used to ensure formant continuity between frames. The user has the option of saving the formant frequency values in a file, by clicking on the '*Save formants*' option next to the 'Help' menu of the formant track window. The two figures below show the spectrogram of the vowel /ae/ in "had", and the corresponding formant track.



t= 29.2 (ms)
f= 471 Hz



Power Spectral Density

This option displays an estimate of the power spectral density (long-time average FFT spectrum) obtained using Welch's method.

<u>RECORD</u>

This option calls Windows' record program from COLEA. It therefore allows you to record a new speech file without having to exit colea. You can also configure the

‘Record’ option to call a more sophisticated record/playback program (e.g., the WaveEditor from SoundBlaster). To do that, edit the file ‘sndcard.cfg’ (in the colea directory) and put the name (including the path) of the record program.

TOOLS

This menu provides some tools for adding noise, filtering, comparing waveforms, and manually segmenting waveforms.

Add white noise

This option adds white Gaussian noise to the signal at an SNR specified by the user. After selecting this option, a small window will appear in which you enter the SNR in dB. After typing the SNR value, hit the <Enter> key.

Add noise from a file

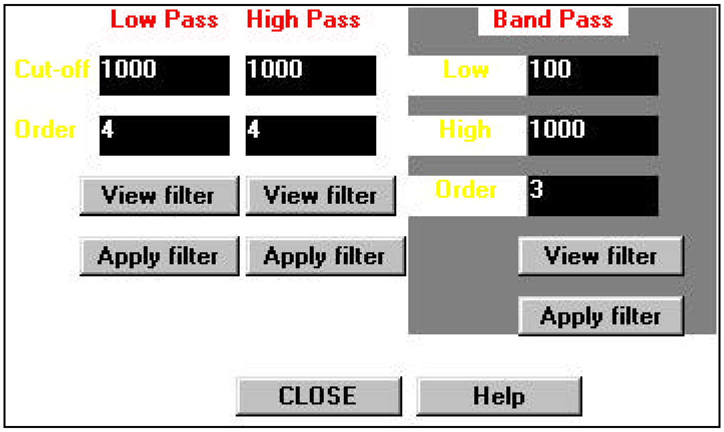
This option adds noise to the speech signal at an SNR specified by the user. The noise is read from a file specified by the user.

Convert to SCN noise

This option converts the speech signal to Signal Correlated Noise (SCN) using a method proposed by Schroeder. This method preserves the shape of the time waveform, but destroys the spectral content of the signal.

Filter tool

This tool can be used to low-pass, high-pass or bandpass the speech signal. The Filter Tool window is shown in Figure 5. You may enter the cutoff frequency as well as the order of the Butterworth filter. Typically, the higher the filter order the steeper the filter roll-off. After entering the cutoff frequency, hit the ‘*Apply filter*’ button to filter the signal. The COLEA window will then be split in two smaller windows, the top being the filtered signal and the bottom being the original (unfiltered) signal.



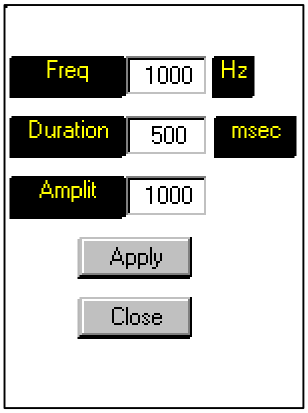
	Low Pass	High Pass
Cut-off	1000	1000
Order	4	4

Band Pass: Low 100, High 1000, Order 3

Figure 5 The Filter Tool window. This tool can be used to low-pass, high-pass or band-pass the signal at cutoff frequencies specified by the user.

Sinewave generator

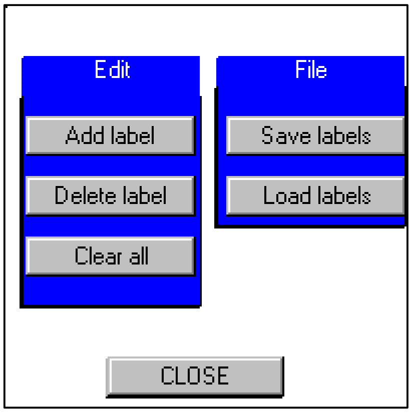
This tool generates sinewaves of various frequencies, amplitudes and durations all specified by the user (see figure on the right). After entering the desired frequency, hit the "Apply" button. The generated sinewaves are tapered at the beginning and end to avoid any clicks.



Freq 1000 Hz
Duration 500 msec
Amplit 1000

Label Tool

This tool can be used for manual segmentation of speech waveforms as well as for displaying time-aligned label files (e.g., TIMIT's .phn files). For instance, this tool can be used to create label files needed for training speech recognition systems.



To load a label file, click on the ‘*Load labels*’ button, and specify the label file. The label files need to be in TIMIT format, that is, they should have the following format:

FromSample ToSample LabelText

…

Example:

0 12000 will

12001 15000 go

The first two numbers in each line are the sample boundaries of the phoneme or word indicated. Figure 6 below shows as an example the time waveform of the TIMIT file ‘sentence.wav’ (included with the colea program) aligned with the corresponding phonetic transcription file ‘sentence.phn’ (also included).

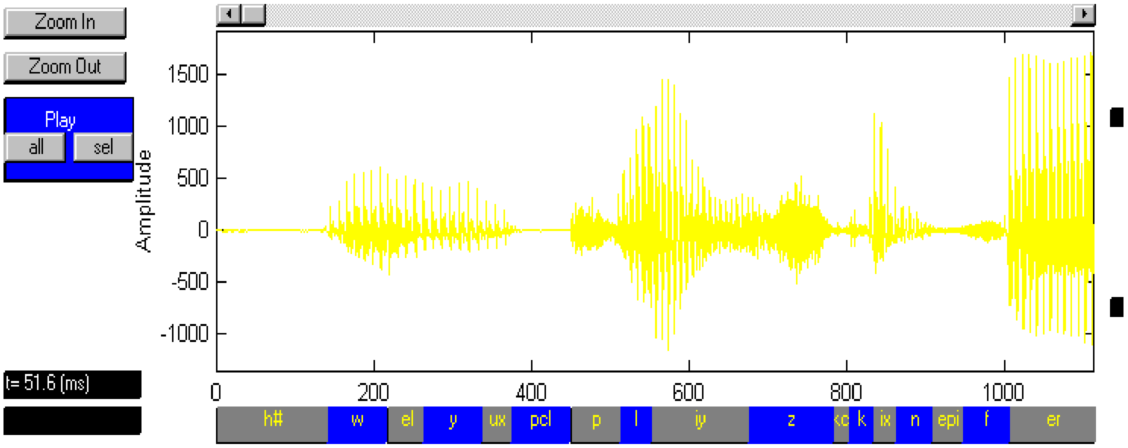


Figure 6 Portion of the waveform of the TIMIT sentence “Will you please confirm government policy regarding waste removal? “ time-aligned with its phonetic transcription using the ‘Load labels’ option of the Label Tool.

To create a label file, first click on the ‘*Add label*’ button, then point the cursor to the beginning of the word (or phoneme, etc.) and press the left mouse button. Next, point the cursor to the end of the word (or phoneme, etc.) and press the right mouse button. A text window should be created which will have the length of the word or phoneme. Enter in the text window the word or phoneme label and hit the <Enter> key. After creating all the labels, then press the '*Save Labels*' button to save the labels in a file in TIMIT format. The figure below shows as an example the labels created for the word "had" - /h ae d/.

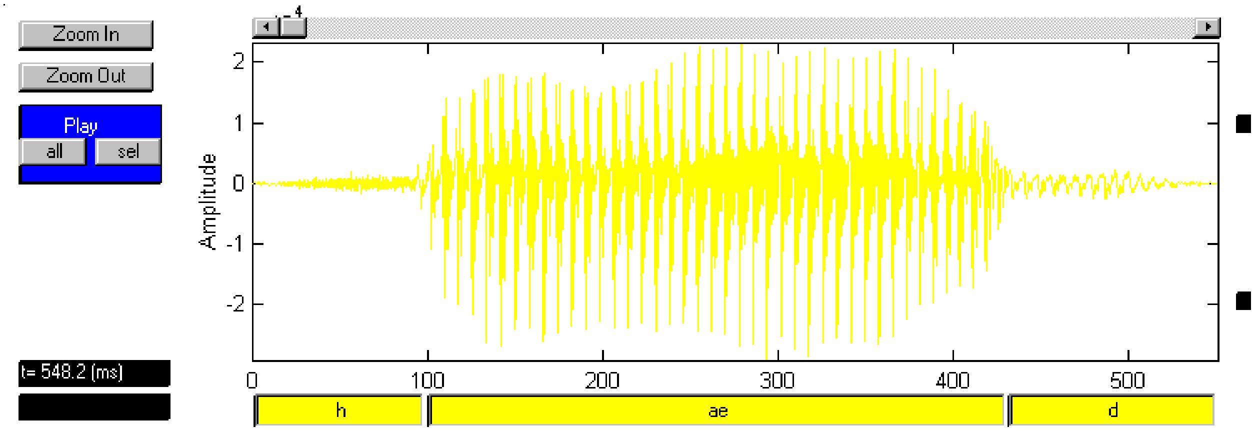
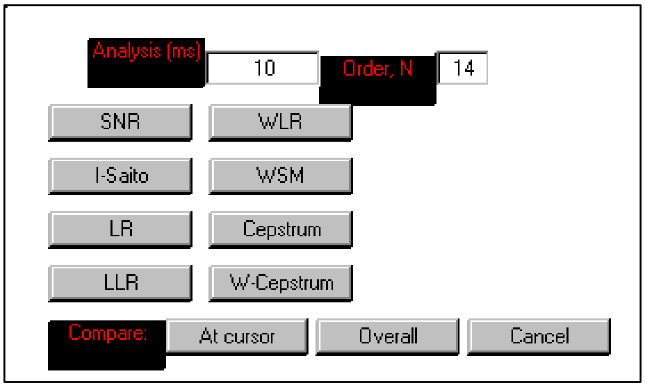


Figure 7 Example of manual segmentation of the word 'had' (/h ae d/) using the Label tool.

Comparison Tool

This tool is used for comparing two waveforms or two frames using either time-domain measures (i.e., SNR) or spectral domain measures (i.e., Itakura-Saito measure) [4][5].


Analysis (ms) 10
Order, N 14

To use this tool, you need first to load two waveforms (using the *Load and Stack* option in the FILE menu), where the top is the approximated (e.g., coded or enhanced) waveform and the bottom waveform is the original waveform.

The user has the option of making an overall (or global) comparison between the two waveforms or a segmental (local) comparison between the two waveforms. The first option is in effect when clicking the button ‘Overall’ (see figure above). In this option, the two speech files are segmented in 10 msec frames (default frame size), and the comparison is performed for each frame. After selecting the distance measure to use, a window is opened at the bottom of the screen showing the values of the distortion measure evaluated every 10-msec frame. To change the default frame size, enter the new value (in msecs) in the ‘*Analysis frame*’ box shown in the Figure above.

In order to compare two particular speech segments of the two files, point to the beginning of the segment and press the left mouse button. Use the bottom window to indicate the beginning of the segment. Then, click on the ‘Cursor’ button (see Figure above), and select the distance measure. A new window will immediately open showing the LPC spectra of the two files. The top spectrum is the LPC spectrum of the original file. The value of the distance measure will be shown as a title.

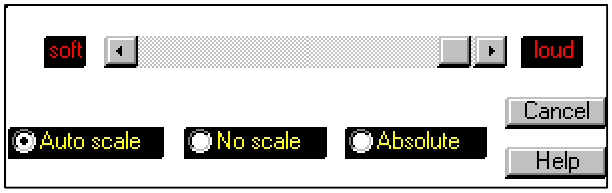
Most of the spectral distortion measures are based on LPC analysis of order 14. To change the LPC order, edit the ‘*Order, N*’ box (see Figure above) and enter the new value. The following distance measures are used [4][5]:

SNR – Signal-to-noise ratio
CEP - Cepstrum
WCEP - Weighted cepstrum (by a ramp)
IS - Itakura-Saito
LR - Likelihood ratio
LLR - Log-likelihood ratio
WLR - Weighted likelihood ratio
WSM - Weighted slope distance metric (Klatt's) [6].

Volume control

This tool is used for adjusting the volume.

There are three different modes:



● Auto scale ○ No scale ○ Absolute

- *Autoscale* (default)

The signal is automatically scaled to the maximum value allowed by the hardware. In this mode, you can not use the slider bar.

- *No scale*

In this mode the signal can be made louder or softer by moving the slider bar.

- *Absolute*

In this mode, the signal is played as is. No scaling is done. Moving the slider bar has no effect.

REFERENCES

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