

MATLAB Functionality for Digital Speech Processing

- MATLAB Speech Processing Code
- MATLAB GUI Implementations

Graphical User Interface

GUI Lite 2.5

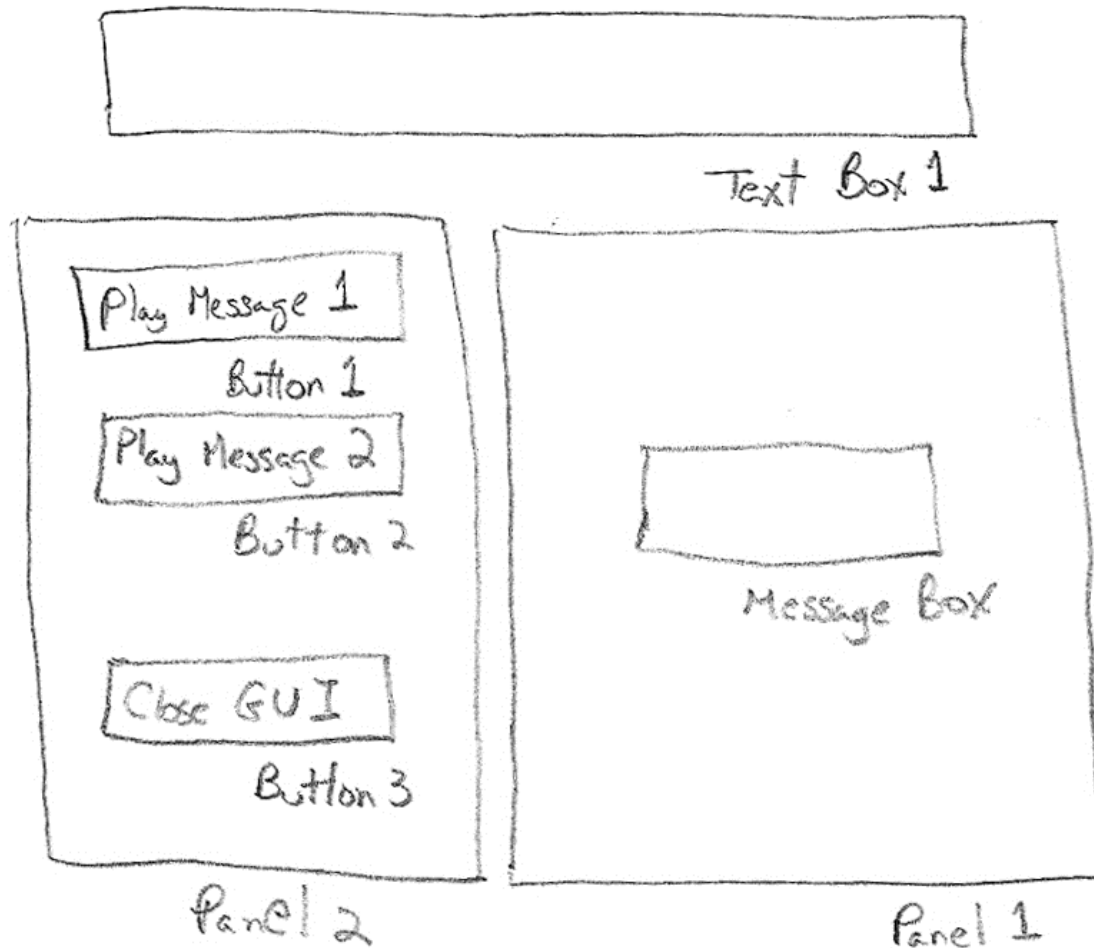
Graphical User Interface Components

- GUI Lite created by students at Rutgers University to simplify the process of creating viable GUIs for a wide range of speech and image processing exercises
- GUI Lite Elements
 - basic design tool and editor (GUI Lite 2.5)
 - panels; used to block group of buttons/graphical panels/etc., into one or more coherent blocks
 - graphics panels; used to display one or more graphical outputs (figures)
 - text block; used to display global information about the specific speech processing exercise
 - buttons; used to get and set (vary) exercise parameters; used to display a list of exercise options; used to initiate actions within the code
 - editable buttons – get and/or set parameter value
 - text buttons – display variable values
 - slider buttons – display variable range
 - popupmenu buttons – display list of variable options (e.g., list of speech files)
 - pushbuttons – initiate actions within the code

GUI LITE 2.5 Design Process

- begin with a rough sketch of the GUI 2.5 output, segmented into button panels, graphics panels, text boxes, and buttons
- run program 'runGUI.m' to create GUI elements and save as a GUI file
- edit the two programs created by GUI LITE 2.5
 - rename GUI program from 'EditrunGUI.m' to 'exercise_GUI25.m'
 - rename GUI Callbacks program from 'PanelandButtonCallbacks.m' to 'Callbacks_exercise_GUI25.m'
- run the resulting exercise and loop on GUI design and Callbacks implementation

Hello/Goodbye World Plan



Design Specs:

- 2 Panels (for linking inputs and outputs)
- 1 Text Box (for describing the Exercise GUI)
- 3 Buttons (all pushbuttons) (for embedding Callback code to play two messages and to close up the GUI)

GUI25 Initial Screen

GUI Lite v2.5

Select Workplace Directory

Current Workplace Directory: C:\data\matlab_gui_current\hello_goodbye_world_gui25

New

Create New GUI

Run 1

Run with runGUI.m File

Run 2

Run w/ .mat & callBack.m Files

Mod

Modify Existing GUI

close

GUI25 Creation for 'hello_goodbye_world'

- run program 'runGUI.m' and click on 'New' button
- enter values for number of panels (2), number of graphics panels (0), number of text boxes (1), and number of buttons (3)
- enter name for GUI ('hello_goodbye_world.mat')
- create the GUI objects specified above, using mouse cursor to define range of each object; set GUI object properties
- save the resulting specifications for the GUI in the designated .mat file
- edit and rename the GUI exercise from 'EditrunGUI.m to 'hello_goodbye_world_GUI25.m'
- edit and rename the GUI Callbacks from 'PanelandButtonCallbacks.m' to 'Callbacks_hello_goodbye_world_GUI25.m'

GUI25 Callback Code

```
% Callback for button 1 – present on screen message 1
function button1Callback(h,eventdata);
    uiwait(msgbox('Hello World!', 'Message1', 'modal'));
```

```
% title box
    stitle1=strcat('Hello World Using GUI2.5');
    set(titleBox1, 'String', stitle1);
    set(titleBox1, 'FontSize', 25);
end
```

```
% Callback for button 3 – Close GUI
function button3Callback(h,eventdata);
    display Goodbye;
    close(gcf);
end
```


run:

hello_goodbye_world_GUI25.m

directory:

hello_goodbye_world_gui25

Hello/Goodbye World

This is a Text Box. Change String Here

Text Box1

Button1 - Pushbutton

Play Message1

Button2 - Pushbutton

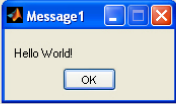
Play Message2

Button3 - Pushbutton

Close GUI

Panel2

Message Box from Code



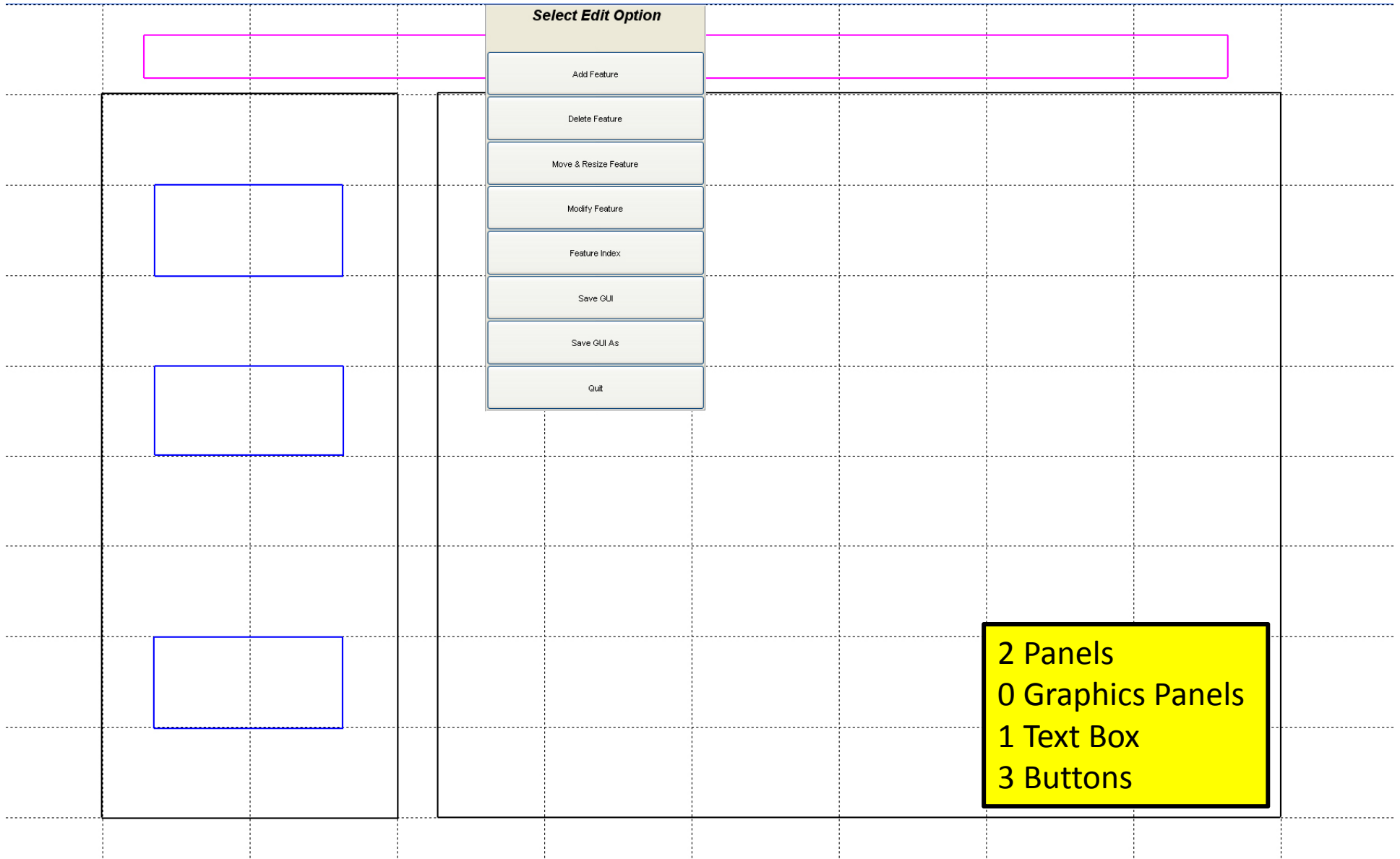
Panel1

The image shows a graphical user interface (GUI) with a light beige background. At the top, there is a text box containing the text "This is a Text Box. Change String Here" and a label "Text Box1". Below this, the interface is divided into two main panels. The left panel, labeled "Panel2", contains three buttons: "Button1 - Pushbutton" with the text "Play Message1", "Button2 - Pushbutton" with the text "Play Message2", and "Button3 - Pushbutton" with the text "Close GUI". The right panel, labeled "Panel1", contains the text "Message Box from Code" and a screenshot of a Windows message box. The message box has a title bar "Message1" and contains the text "Hello World!" with an "OK" button.

Hello/Goodbye World GUI

- Run program 'runGUI.m' to bring up GUI Lite 2.5 editor
- Choose Mod (modify) and select GUI file 'hello_goodbye_world.mat' for editing
- Choose 'Move & Resize Feature' option
- Choose 'Button' option
- Left click inside button to be modified
- Choose new button coordinates by using graphics cursor to identify lower left and upper right corners of modified button
- Click 'Save GUI' button
- Iterate on other buttons
- Click 'Quit' option to terminate GUI Lite 2.5 editor

GUI Lite 25 Edit Screen



GUI LITE 2.5 Edit Screen

Select Edit Option
Add Feature
Delete Feature
Move & Resize Feature
Modify Feature
Feature Index
Save GUI
Save GUI As
Quit

Add Feature

Delete Feature

Move & Resize Feature

Modify Feature

Feature Index

Save GUI

Save GUI As

Quit

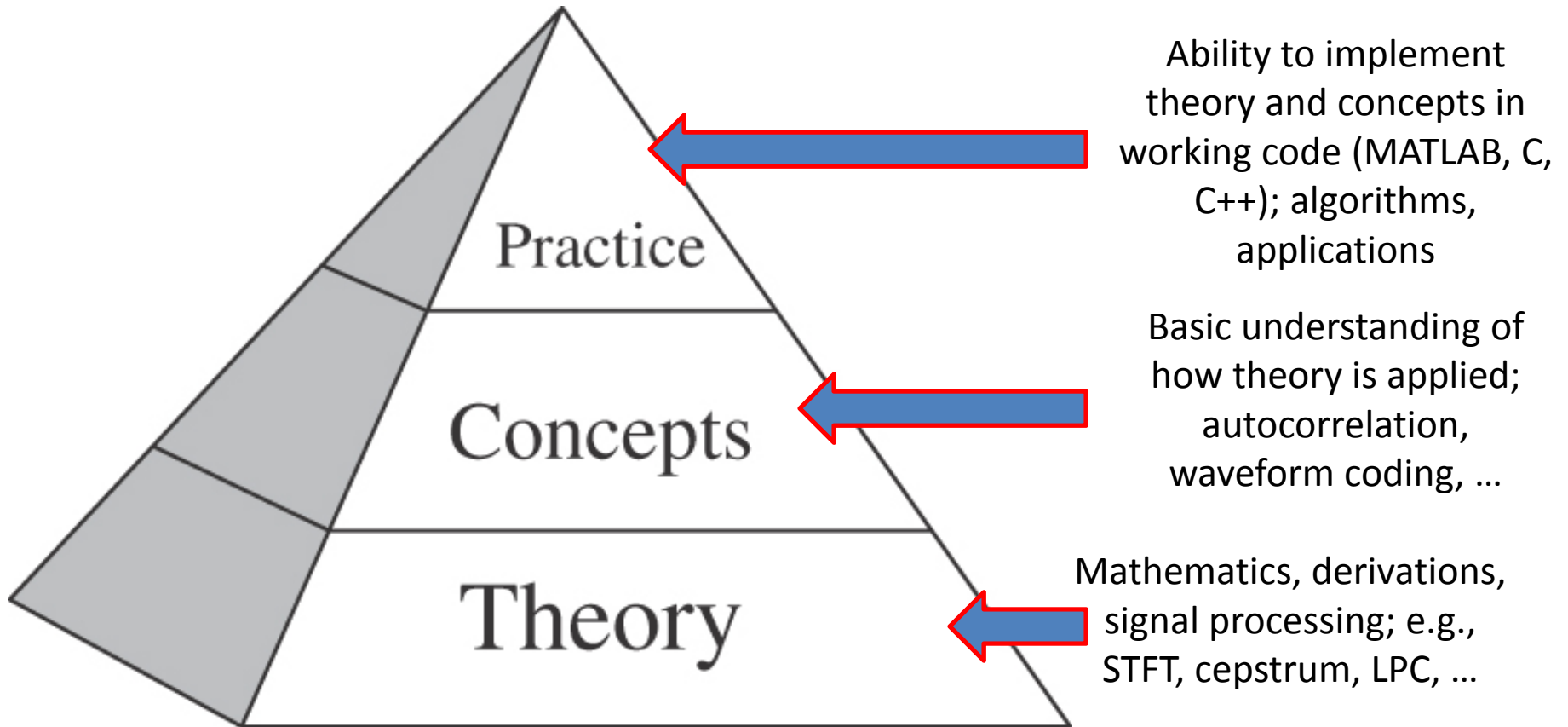
GUI Lite 25 Features

- separates GUI design from Callbacks for each GUI element
- provides a versatile editor for modifying GUI elements without impacting the Callback actions
- provides a GUI element indexing feature that enables the user to identify GUI elements with the appropriate Callback elements

Missing GUIDE Features

- radio button
- check box
- listbox
- toggle button
- table
- axes
- button group
- active X control
- are the missing features of value?
- do we need these features?
- can we create the desired set of speech processing exercises without these features?
- can we add these features to the GUI LITE editor?

Digital Speech Processing



Need to understand speech processing at all three levels

The Speech Stack

Speech Applications — coding, synthesis, recognition, understanding, verification, language translation, speed-up/slow-down

Speech Algorithms — speech-silence (background), voiced-unvoiced, pitch detection, formant estimation

Speech Representations — temporal, spectral, homomorphic, Linear Prediction Coding

Fundamentals — acoustics, linguistics, pragmatics, speech production/perception

Basics – read/write speech/audio files; display speech files; play files

MATLAB Exercise Categories

- Basic MATLAB Functions for handling speech and audio files
- Advanced MATLAB Functions for Speech Processing

MATLAB Exercise Categories

- The speech processing exercises are grouped into 5 areas, namely:
 - **Basics** of speech processing using MATLAB (5)
 - **Fundamentals** of speech processing (6)
 - **Representations** of speech in time, frequency, cepstrum and linear prediction domains (22)
 - **Algorithms** for speech processing (7)
 - **Applications** of speech processing (17)

Basic Functionality

- **read a speech file** (i.e., open a .wav speech file and read the speech sample into a MATLAB array)
- **write a speech file** (i.e., write a MATLAB array of speech samples into a .wav speech file)
- **play a MATLAB array** of speech samples as an audio file
- * **play a sequence of MATLAB arrays of speech samples** as a sequence of audio files
- **record a speech file** into a MATLAB array
- **plot a speech file** (MATLAB array) as a waveform using a strips plot format
- * **plot a speech file** (MATLAB array) as one or more 4-line plot(s)
- **convert the sampling rate** associated with a speech file (MATLAB array) to a different (lower/higher) sampling rate
- **lowpass/highpass/bandpass filter** a speech file (MATLAB array) to eliminate DC offset, hum and low/high frequency noise
- **plot a frame of speech** and its associated spectral log magnitude
- **plot a spectrogram** of a speech file (MATLAB array)
- * **plot multiple spectrograms** of one or more speech files (MATLAB arrays)

* indicates exercise not yet done

Read a Speech File into a MATLAB Array

- `[xin, fs, nbits] = wavread(filename);`
- `[xin, fs] = loadwav(filename);`
 - filename is ascii text for a .wav-encoded file which contains a speech signal encoded using a 16-bit integer format
 - xin is the MATLAB array in which the speech samples are stored (in double precision format)
 - fs is the sampling rate of the input speech signal
 - nbits is the number of bits in which each speech sample is encoded (16 in most cases)
 - program wavread scales the speech array, xin, to range $-1 \leq xin \leq 1$, whereas loadwav preserves sample values of the speech file and hence array xin is scaled to range $-32768 \leq xin \leq 32767$
- `[xin1, fs, nbits] = wavread('s5.wav');`
- `[xin2, fs] = loadwav('s5.wav');`

Read a Speech File into a MATLAB Array

- % test_wavread.m
- % test wavread function
- %
- % read speech samples from file 'test_16k.wav' into array x1 using wavread
- % routine
- filein='test_16k.wav';
- [x1,fs1,nbits]=wavread(filein);
-
- % print out values of fs1, nbits, wavmin1, wavmax1
- wavmin1=min(x1);
- wavmax1=max(x1);
- fprintf('file: %s, wavmin/wavmax: %6.2f %6.2f, fs1: %d, nbits: %d \n',...
- filein,wavmin1,wavmax1,fs1,nbits);
-
- % read speech samples from same file into array x2 using loadwav routine
- [x2,fs2]=loadwav(filein);
-
- % print out values of fs2, nbits, wavmin2, wavmax2
- wavmin2=min(x2);
- wavmax2=max(x2);
- fprintf('file: %s, wavmin/wavmax: %d %d, fs2: %d \n',...
- filein,wavmin2,wavmax2,fs2);

Terminal Display:

file: test_16k.wav, wavmin/wavmax: -1.00 1.00, fs1: 16000, nbits: 16

file: test_16k.wav, wavmin/wavmax: -32768 32767, fs2: 16000

Write a Speech Array into a Speech File

- `wavwrite(xout, fs, nbits, filename);`
- `savewav(xout, filename, fs);`
 - `xout` is the MATLAB array in which the speech samples are stored
 - `fs` is the sampling rate of the output speech signal
 - `nbits` is the number of bits in which each speech sample is encoded
 - `filename` is the ascii text for the .wav-encoded file in which the MATLAB signal array is to be stored
 - for `wavwrite` the MATLAB array `xout` needs to be scaled to the range $-1 \leq x_{in} \leq 1$ whereas for `savewav` the MATLAB array `xout` needs to be scaled to the range $-32768 \leq x_{out} \leq 32767$
- `wavwrite(xin1, fs, 's5out.1.wav');`
- `savewav(xin2, 's5out.2.wav', fs);`

Record/Display Speech

Basics

Record_Display_Speech -- file:we were away a year ago Irr.wav

Speech Directory: we were away a year a...

Plot Speech

Play Speech

8000 fs: recording sampling rate

2 nsec: recording duration in seconds

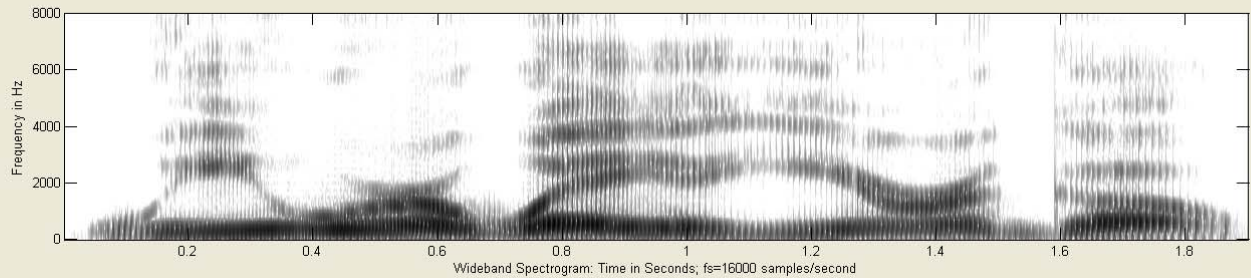
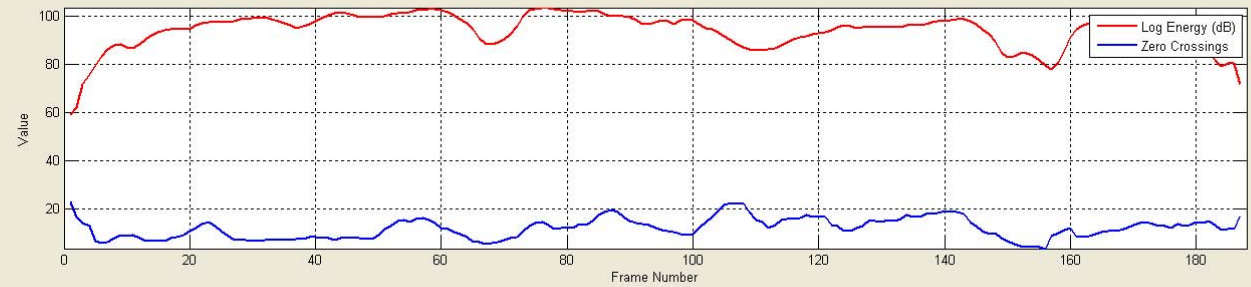
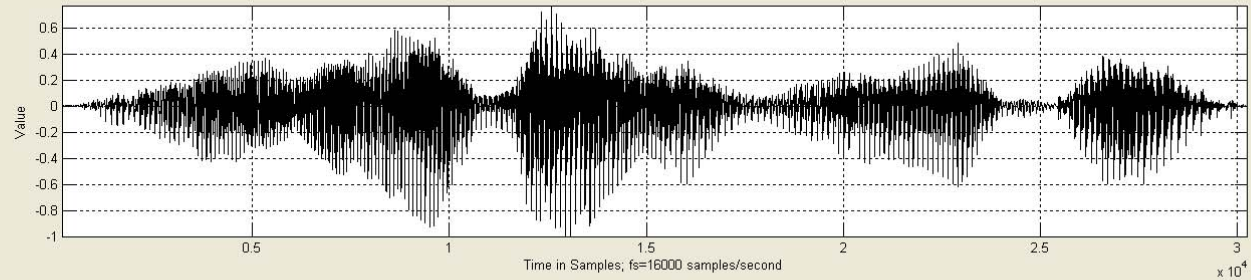
Record Speech

Endpoint Speech

out_file fileName: file to save recording

Save Speech Speech Directory

Close GUI



Play a Speech File

- `sound(x, fs);`
- `soundsc(x, fs);`
 - for `sound` the speech array, `x`, must be scaled to the range $-1 \leq x \leq 1$
 - for `soundsc` any scaling of the speech array can be used
 - `fs` is the sampling rate of the speech signal
- `[xin, fs] = loadwav('s5.wav');` % load speech from s5.wav;
- `xinn = xin/abs(max(xin));` % normalize to range of - 1 to 1;
- `sound(xinn, fs);` % play out normalized speech file;
- `soundsc(xin, fs);` % play out unnormalized speech file;

* Play Multiple Speech Files

- `play_multiple_files.m`;
 - sequence of filenames read in via `filelist`, `keyboard` or `file search`
- Example of usage to play out 3 speech files in sequence:
 - `kbe=filename` entry via `filelist(2)`, `keyboard(1)`, or `file search(0):1`; %
keyboard chosen
 - `N=number of files to be played in a group:3`; % play out 3 files
 - `i=1; filename: s1.wav`;
 - `i=2; filename: s2.wav`;
 - `i=3; filename: s3.wav`

* Play Multiple Speech Files

- test_play_files.m
 - play the following sequence of files:

s2.wav

s3.wav

s4.wav

s5.wav

s6.wav



Record Speech into MATLAB Array

- record_speech.m (calls MATLAB function audiorecorder.m, formally wavrecord.m)
- function y=record_speech(fs, nsec);
 - fs: sampling frequency
 - nsec: number of seconds of recording
 - y: speech samples array normalized to peak of 32767

Display Speech Waveform

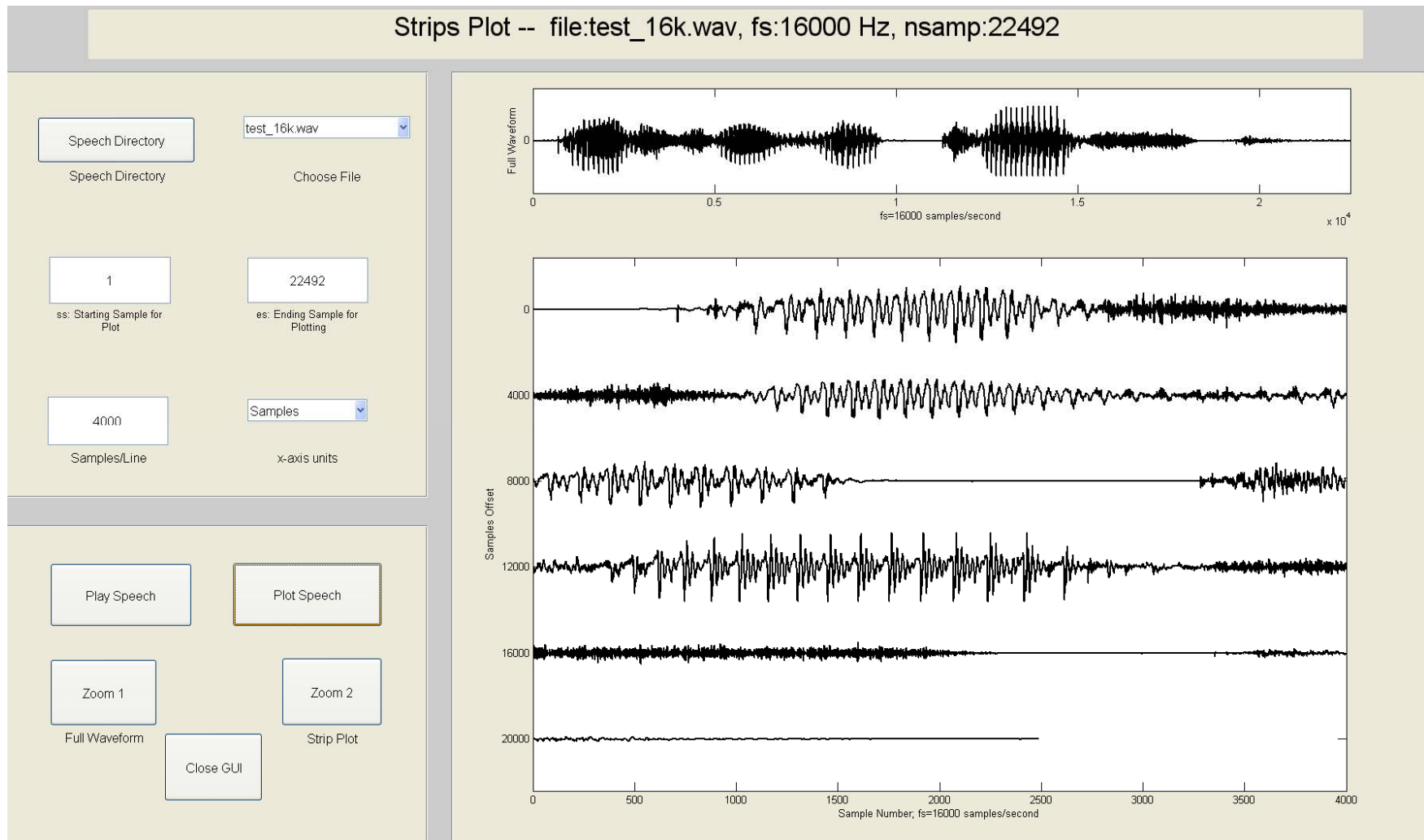
Strips Plot

*** 4-Line Plots**

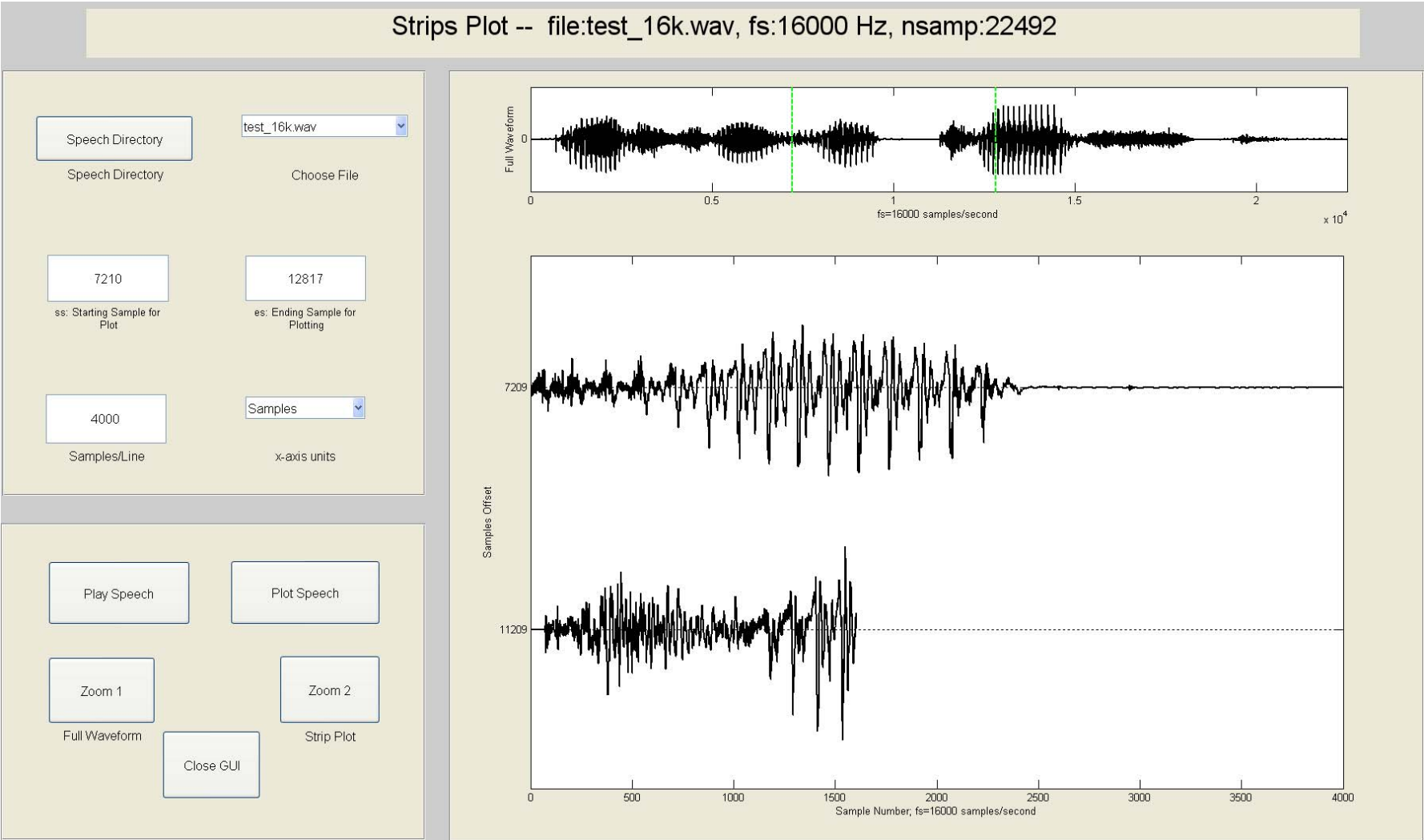
Waveform Zoom Strips Plot

- Plotting and examining speech/audio waveforms is one of the most useful ways of understanding the properties of speech and audio signals.
- This MATLAB Exercise displays a speech/audio waveform as a single running plot of samples (called a Strips Plot).
- Exercise plots from designated starting sample to designated ending sample, with a user-specified number of samples/line.
- Zoom feature to select region of signal for display.
- Plots use either samples or seconds, as specified by the user.

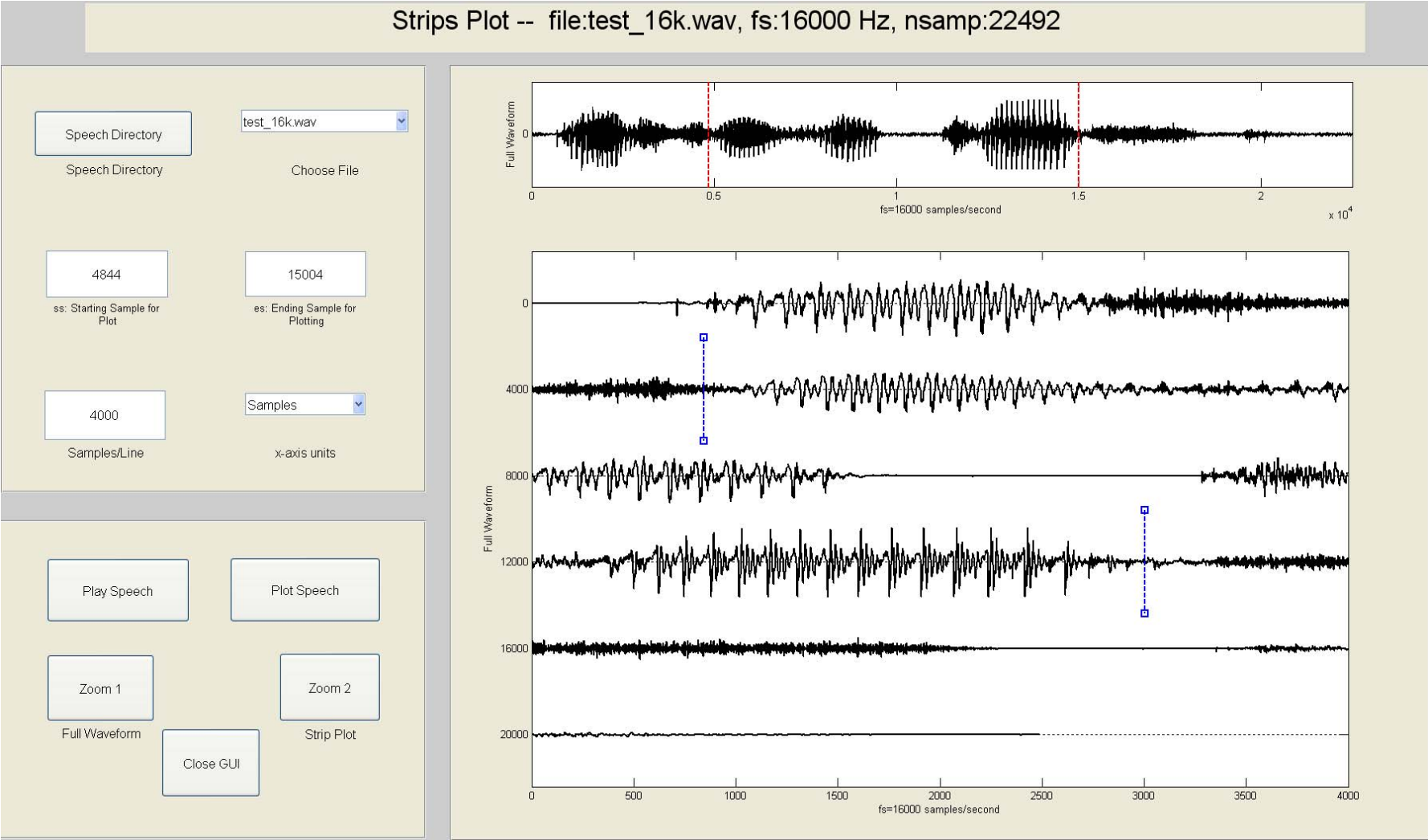
Waveform Strips Plot



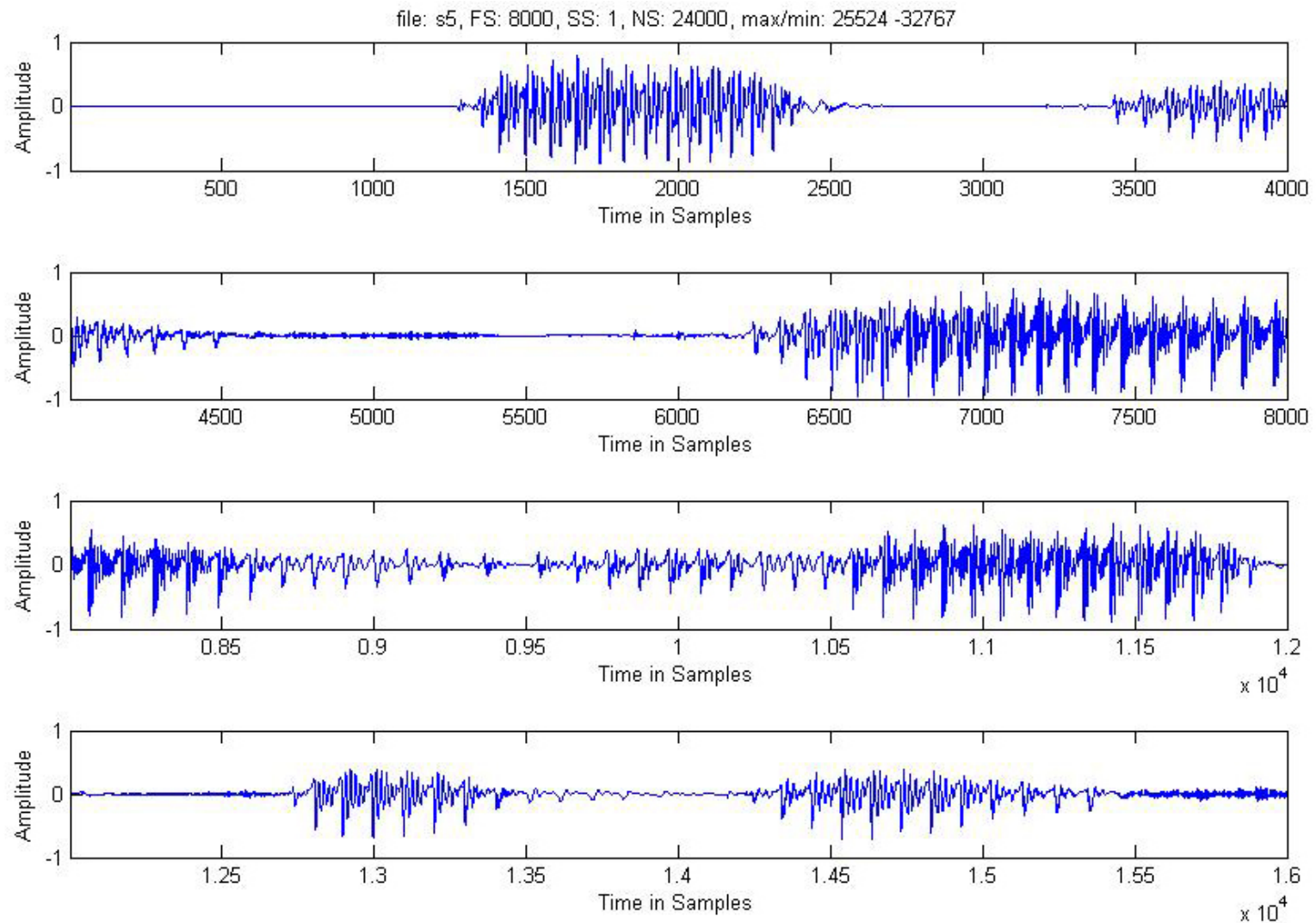
Waveform Strips Plot – Zoom 1



Waveform Strips Plot – Zoom 2



* Plot Speech Using 4-Line Plot



Sampling Rate Conversion

- `y = srconv(x, fsin, fsout);`
 - `x`: input speech array;
 - `fsin`: input speech sampling rate;
 - `fsout`: desired speech sampling rate;
- Example:
 - `[xin, fsin] = loadwav('s5.wav');` % `fsin=8000;`
 - `fsout = 10000;` % desired sampling rate;
 - `y = srconv(xin, fsin, fsout);`

Sampling Rate Conversion

Sampling Rate Conversion -- file:1A.waV, fs:20000 Hz, nsamp:15872

Speech Directory

1A.waV

Play Original Signal

Plot Original Signal Waveform

Plot Original Signal Long Time Spectrum

10000

Output_File_Conv

fs for converted file Converted Speech Filename

Convert Sampling Rate

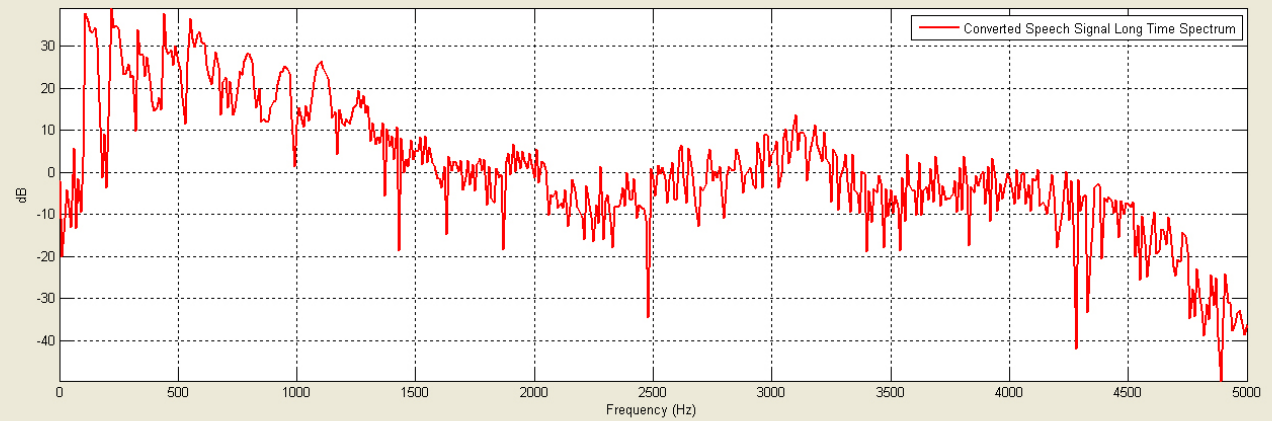
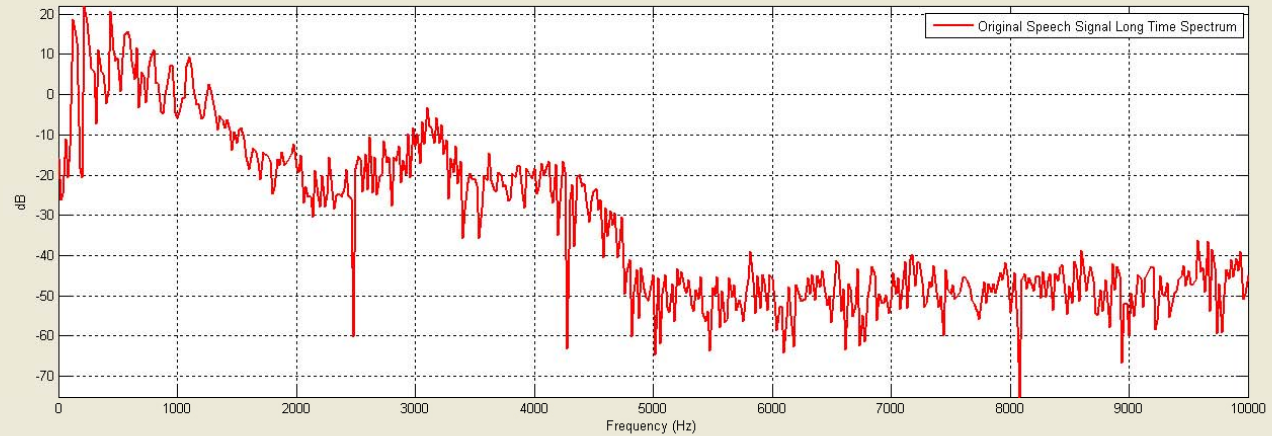
Play Converted Speech Signal

Plot Converted Speech Signal

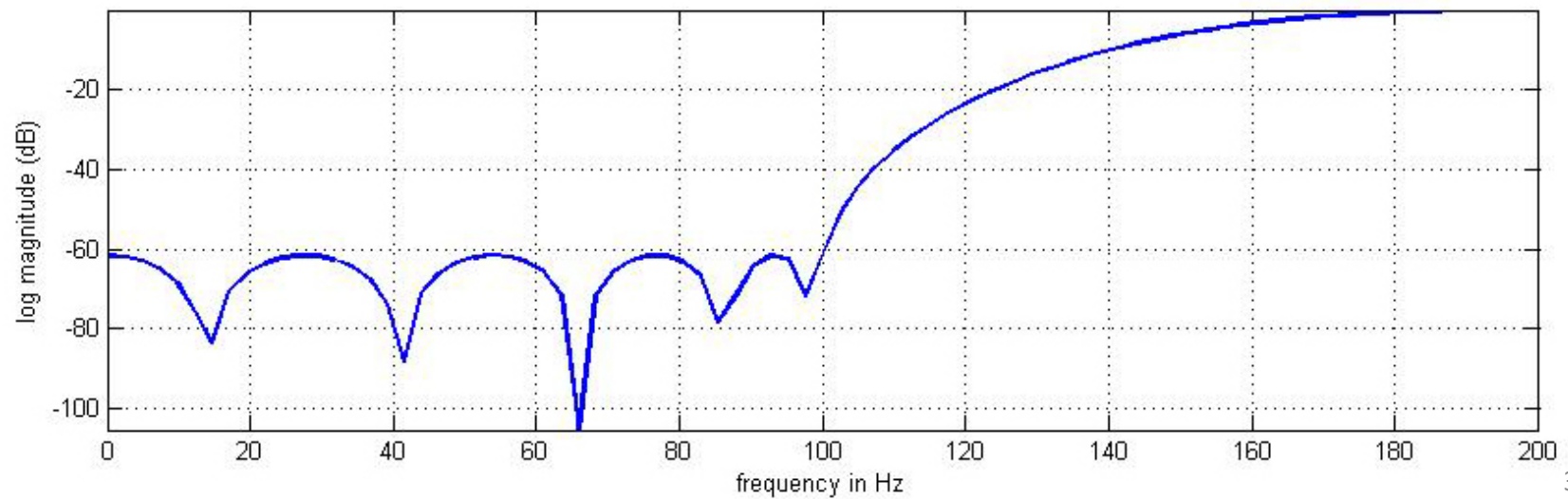
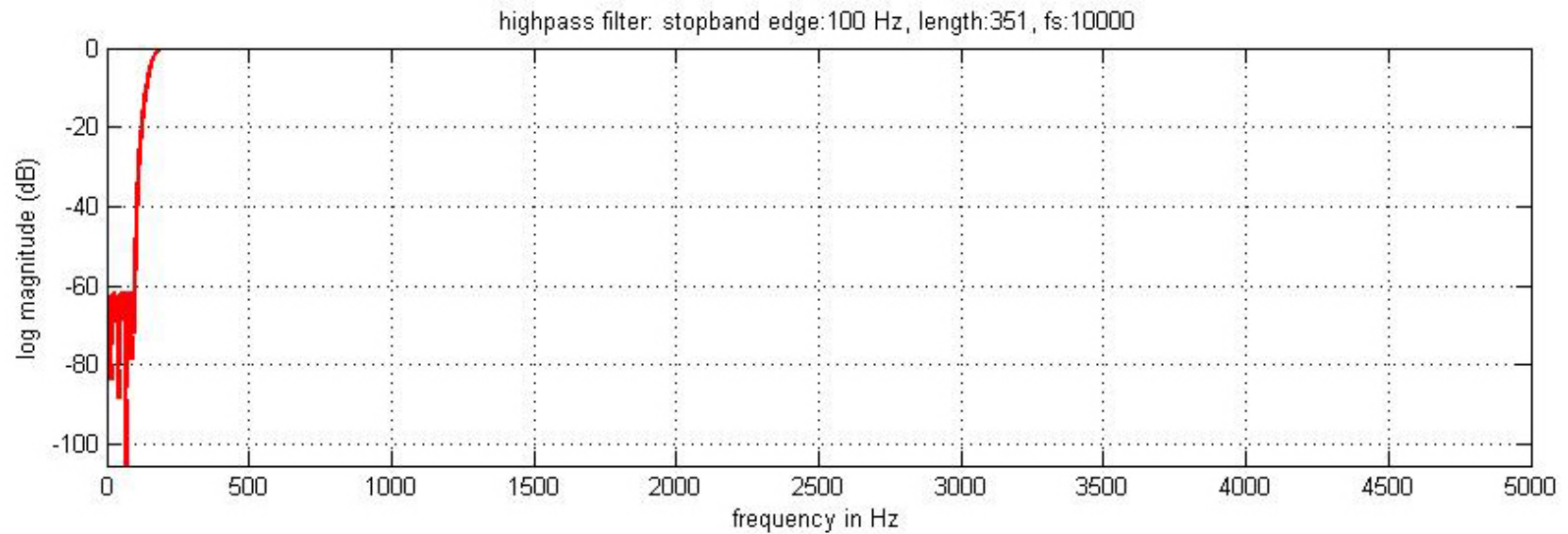
Plot Converted Speech Long Time Spectrum

Save Converted Speech in File

Close GUI

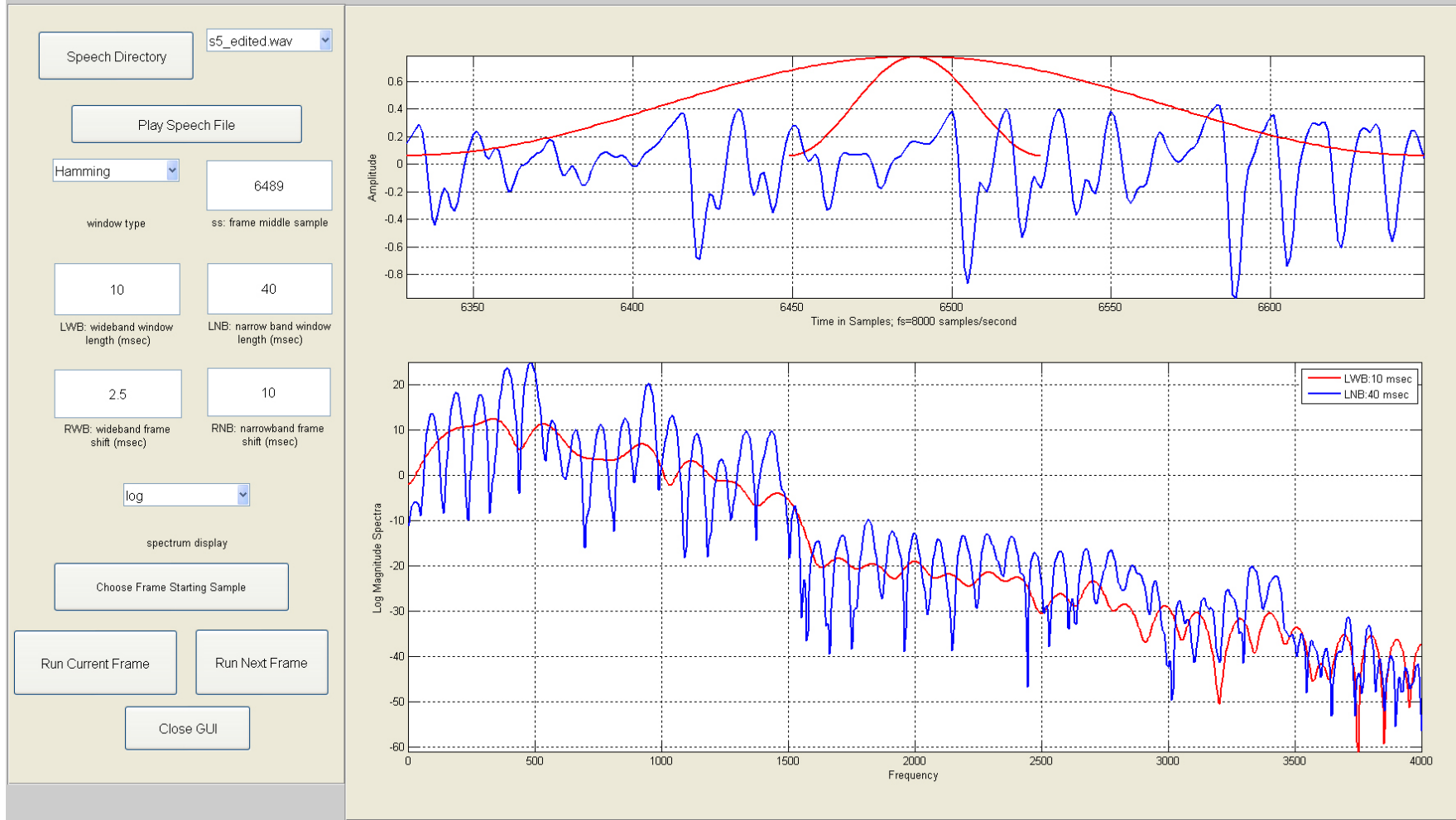


Filter Speech Waveform

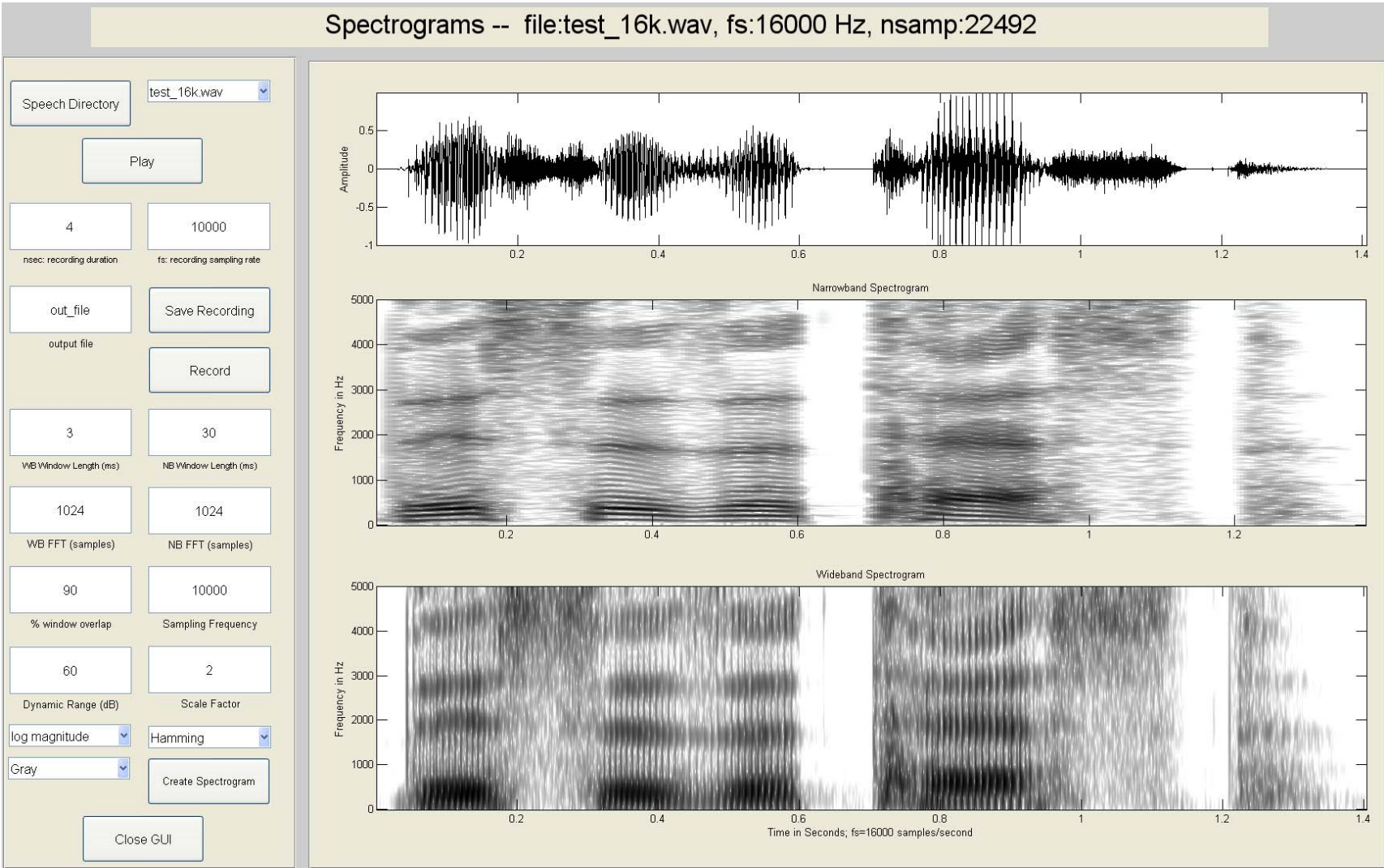


Frame-Based Spectrums

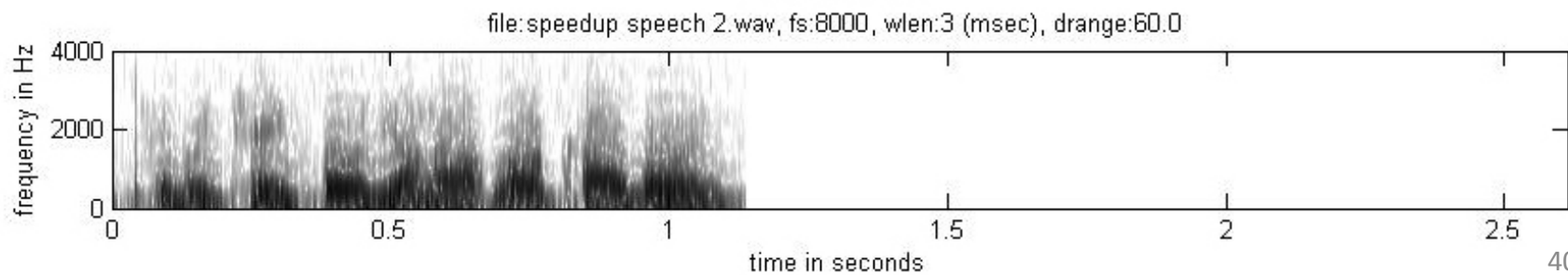
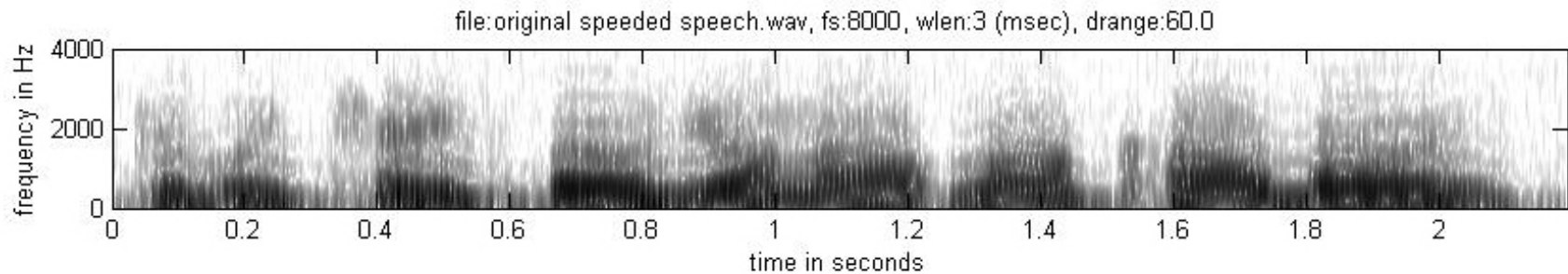
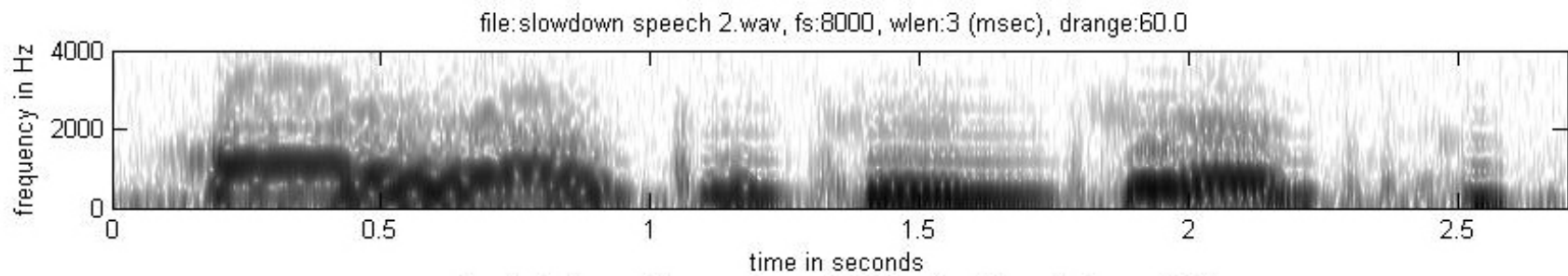
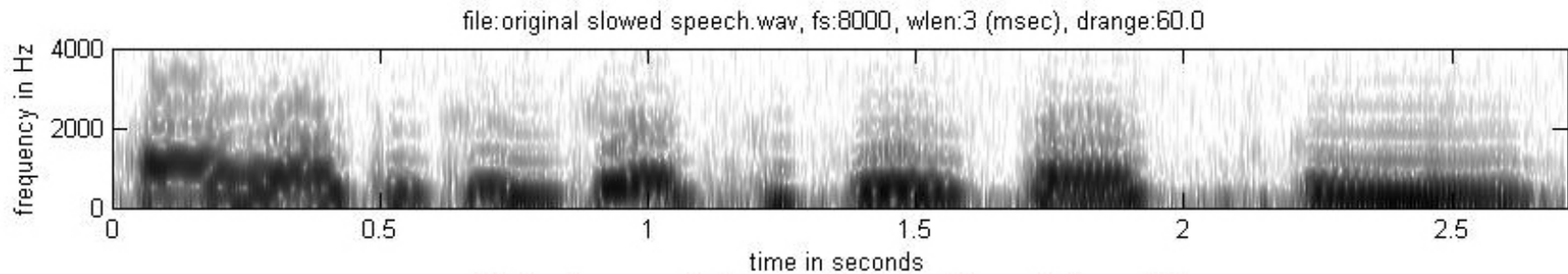
HW magnitude/log magnitude spectra -- file: s5_edited.wav, middle sample: 6489, window lengths (msec): 10 40



Wideband/Narrowband Spectrogram



* Plot Multiple Spectrograms



Fundamentals

- 2-tube vocal tract model
- 3-tube vocal tract model
- p-tube vocal tract model
- glottal pulse model and spectrum
- composite vocal tract model and spectrum
- ideal vocal tract model and spectrum

Representations

- **time domain exercises**
 - windows; features; autocorrelation estimates; amdf
- **frequency domain exercises**
 - phase/magnitude; overlap-add windows; WSOLA
- **cepstral domain exercises**
 - analytical cepstrum; single pole cepstrum; FIR sequence cepstrums; cepstrum aliasing; cepstrum liftering; cepstral waterfall
- **linear prediction exercises**
 - LPC frames; LPC error; LPC varying p ; LPC varying L ; LSP roots; plot roots

Algorithms

- endpoint detector
- Voiced-Unvoiced-Background estimation method
- autocorrelation pitch detector
- log harmonic spectral waterfall plots
- cepstral pitch detector
- SIFT pitch detector
- formant estimation method

Applications – Part 1

- Speech waveform coding;
 - statistical properties of speech; quantization characteristics of a B-bit uniform or mu-law compressed and quantized speech file; uniform quantization; mu-law compression; mu-law quantization; Signal-to-Noise Ratio (SNR) of uniform and mu-law quantizers
- Automatic Gain Control (AGC)
- Adaptive Differential Pulse Code Modulation (ADPCM) waveform speech coder
- Vector Quantizer (VQ); VQ Cells
- Synthetic vowel synthesizer

Applications – Part 2

- LPC error synthesis
- LPC vocoder
- Play pitch period contour
- Two-Band subband coder
- Phase Vocoder
- Isolated, speaker-trained, digit recognizer

Summary

- Set of about 60 MATLAB speech processing exercises
- Exercises aligned with distinct sections in the textbook TADSP by Rabiner/Schafer
- Each exercise has an associated Graphical User Interface created using a GUI LITE program and created expressly for these speech processing exercises
- GUI LITE design and implementation Callbacks are in totally separate code packages

MATLAB Central APPs

- **Search:** Matlab Central
- **Click on:** 'File Exchange'
- **Local Search:** 'speech processing exercises'
- **Click on desired exercise** (be sure to download speech/audio files before downloading any exercise: e.g., Zoom Strips Plot)
- **Click on** downloaded exercise to get to user guide information

MATLAB Central APPs

matlab central - Google Search - Mozilla Firefox

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www.mathworks.com/matlabcentral/

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start

Lecture 2_winte...

Matlab_speech_...

MATLAB R2012b

Editor - C:\data\...

matlab central - ...

1:18 PM

MATLAB Central APPs

The screenshot shows the MATLAB Central File Exchange page in a Mozilla Firefox browser. The browser's address bar displays `www.mathworks.com/matlabcentral/fileexchange/`. The page features the MATLAB Central logo at the top left and a search bar with the text "File Exchange". Below the search bar, there are navigation links for "File Exchange", "Answers", "Newsgroup", "Link Exchange", "Blogs", "Trendy", "Cody", "Contest", and "MathWorks.com".

The main content area is titled "File Exchange" and includes a search bar with the text "speech processing exercises". Below the search bar, there is a "Browse" section with icons and links for "Functions", "Apps", "Examples", "Simulink Models", "Videos", "Instrument Drivers", and "Hardware Support Packages".

On the right side, there are two featured items:

- Most Recent** (see all): "Volumetric Data Explorer" by Adam Filion. It has a 5-star rating and a description: "App for exploring higher dimensional data using volumetric visualizations and animation." The image shows a 3D surface plot.
- Most Popular** (see all): "export_fig" by Oliver Woodford. It has a 5-star rating and a description: "Exports figures nicely to a number of vector & bitmap formats." The image shows a 3D surface plot with a smaller inset image.

The browser's taskbar at the bottom shows several open applications, including "Lecture 2...", "Matlab_spe...", "MATLAB R2...", "Editor - C:\...", "File Exchan...", and "Adobe Phot...". The system clock shows 1:21 PM.

MATLAB Central APPs

The screenshot shows a Mozilla Firefox browser window displaying search results for 'speech processing exercises' on the MATLAB Central File Exchange. The browser's address bar shows the URL: `www.mathworks.com/matlabcentral/fileexchange/index?page=2&term=speech+processing+exercises&utf8=✓`. The search results are filtered by 'matlab central' and show a list of applications with their descriptions, update dates, and statistics.

Refine by Content Type

Function	53
App	27

Refine by Category

Data Analysis	48
GUI Development	31

Refine by Product

MATLAB	49
--------	----

Refine by Time Frame

All Time	
Last 30 Days	
Last 7 Days	

Search Results:

- Rosenberg Glottal Pulse**
Computes the discrete-time rosenberg glottal pulse approximation in the time and frequency domains. (speech processing, vocal tract, gui)
Updated 4 months ago
0 Ratings, 0 Comments, 13 Downloads (30 Days)
fx Callbacks_glottal_pulse_GUI25(f,C)
fx glottal_pulse_GUI25
- Filter Signal** by Speech Processing
This exercise enables the user to design a filter and then process an existing speech or audio file. (gui, speech processing, signal processing)
Updated 5 months ago
0 Ratings, 0 Comments, 50 Downloads (30 Days)
fx Filter Signal
fx Callbacks_filter_GUI25(f,C,start_path)
fx Dinfinity(deltap,deltas)
- Zoom Strips Plot** by Speech Processing
This exercise provides a simple way to visualize and understand speech waveform properties. (gui, speech processing, signal processing)
Updated 5 months ago
0 Ratings, 0 Comments, 5 Downloads (30 Days)
fx Zoom Strips Plot
fx Callbacks_strips_plot_GUI25(f,C,start_path)
fx EditrunGui
- Speech and Audio Files for Speech Processing Exercises** by Speech Processing
A set of speech and audio files recorded with a range of sampling rates and varying duration. (speech processing, teaching)
Updated 5 months ago
0 Ratings, 0 Comments, 91 Downloads (30 Days)
- Echo Signal** by Speech Processing
Allows user to create an echoed version of an existing speech file and compare it to the original. (gui, speech processing, signal processing)
Updated 5 months ago
0 Ratings, 0 Comments, 11 Downloads (30 Days)
fx (0:(NB-1))/Nfft * fs;
end
fx Callbacks_echo_signal_GUI25(f,C,start_path)

www.mathworks.com/matlabcentral/fileexchange/authors/373534

MATLAB Central APPs

The screenshot shows a web browser window with the title "Zoom Strips Plot - File Exchange - MATLAB Central - Mozilla Firefox". The address bar shows the URL "www.mathworks.com/matlabcentral/fileexchange/42923-zoom-strips-plot". The page content includes the MATLAB Central logo, a search bar with "File Exchange" entered, and navigation links like "File Exchange", "Answers", "Newsgroup", "Link Exchange", "Blogs", "Trendy", "Cody", "Contest", and "MathWorks.com".

The main content area features a dark header "File Exchange" and a central card for "Zoom Strips Plot" by "Speech Processing". The card includes a thumbnail image of the app's interface, the text "This exercise provides a simple way to visualize and understand speech waveform properties.", and a "Watch this File" button. To the right of the card, a box states "Be the first to rate this file!", "5 Downloads (last 30 days)", "File Size: 1.44 MB", and "File ID: #42923".

Below the card is a "File Information" section with a "Description" that reads: "THE SET OF SPEECH AND AUDIO FILES HAVE TO BE DOWNLOADED AND SAVED IN THE SAME FOLDER TO WHICH YOU DOWNLOAD THE VARIOUS SPEECH PROCESSING EXERCISES IN ORDER FOR THIS PROGRAM TO WORK SEAMLESSLY. THE SPEECH AND AUDIO FILES CAN BE DOWNLOADED USING THE FOLLOWING LINK: <http://www.mathworks.com/matlabcentral/fileexchange/42911-speech-and-audio-files-for-speech-processing-exercises?download=true> WE STRONGLY URGE YOU TO DOWNLOAD THE SPEECH AND AUDIO FILES BEFORE DOWNLOADING ANY OF THE SPEECH PROCESSING EXERCISES. Speech processing designates a team consisting of Prof. Lawrence Rabiner (Rutgers University and University of California, Santa Barbara), Prof. Ronald Schafer (Stanford University), Kirty Vedula and Siva Yedathi (Rutgers University). This exercise is one of a set of speech processing exercises that are intended to supplement the teaching material in the textbook "Theory and Applications of Digital Speech Processing" by L R Rabiner and R W Schafer. Plotting and examining speech waveforms is one of the most useful ways of understanding the properties of speech."

On the right side of the page, there are two "Download" buttons: "Download App" and "Download Submission". Below these is a note "Code covered by the BSD License". A "Highlights from Zoom Strips Plot" section lists several files with their descriptions, such as "Callbacks_strips_plot_GUI...", "EditrunGui", "plot_strips(xinn,n,ystart...", and "strips_modified(x,sd,vsta...". A "View all files" link is also present.

The browser's taskbar at the bottom shows several open applications: "Lecture 2...", "Matlab_spe...", "MATLAB R2...", "Editor - C:\...", "Zoom Strips...", and "Adobe Phot...". The system clock shows "1:23 PM".