MATLAB Exercise – Complex Cepstrum Computation Examples

Program Directory: `matlab_gui\cepstrum_computation_fir`
Program Name: `complex_cepstrum_fir_GUI25.m`
GUI data file: `complex_cepstrum_fir.mat`
Callbacks file: `Callbacks_complex_cepstrum_fir_GUI25.m`
TADSP: Problem 8.12

This MATLAB exercise compares and contrasts three algorithms for computing the complex cepstrum of two finite duration sequences. The three methods are the analytical method (with root finding using the MATLAB function `roots`), the conventional cepstral computation using the MATLAB signal processing toolbox function `cceps`, and the conventional FFT method of cepstral computation based on computing the inverse Fourier transform of the complex logarithm of the Fourier transform of the signal (with phase unwrapping).

Complex Cepstrum Computation Examples – Theory of Operation

In this MATLAB Exercise you are given two finite duration sequences ($x[n], y[n]$) of the form:

1. $x[n] = \delta[n] + \alpha * \delta[n - N_p]$, and
2. $y[n] = \begin{cases} \alpha^n \sin\left[\dfrac{2\pi n}{N_p}\right] & 0 \le n \le N_p - 1 \\ 0 & \text{otherwise} \end{cases}$

where the default values are $\alpha = 0.85$ and $N_p = 100$ for the sequence $x[n]$, and $\alpha_1 = 0.99$ and $N_p = 100$ for the sequence $y[n]$. For each of these finite duration sequences the exercise computes the complex cepstrum using three different mthods, namely the analytical method (with root finding), the conventional approach using the MATLAB Signal Processing Toolbox function `cceps`, and the conventional approach using a finite length FFT, phase unwrapping, a complex logarithm, and an inverse FFT.

Complex Cepstrum Computation Examples – GUI Design

The GUI for this exercise consists of two panels, 4 graphics panels, 1 title box and 5 buttons. The functionality of the two panels is:

1. one panel for the graphics display,
2. one panel for parameters related to the pair of FIR sequences, and for running the program.

The set of four graphics panels is used to display the following:

1. the FIR sequence (either sequence 1 ($x[n]$) or sequence 2 ($y[n]$)),
2. the log magnitude response of the FIR sequence,
3. the unwrapped and wrapped phase of the FIR sequence frequency response,
4. the set of complex cepstrums obtained using the direct cepstrum analysis method and the MATLAB routine.

The title box displays the information about the FIR sequence parameters. The functionality of the 5 buttons is:

1. an editable button that specifies the FIR sequence parameter `alpha`; (the default value is `alpha=0.85`),
2. an editable button that specifies the FIR sequence parameter `Np`; (the default value is $N_p = 100$),
3. a pushbutton to run the code and display the results of short-time cepstral analysis using FIR sequence 1,
4. a pushbutton to run the code and display the results of short-time cepstral analysis using FIR sequence 2,
5. a pushbutton to close the GUI.

Complex Cepstrum Computation Examples – Scripted Run

A scripted run of the program ’complex_cepstrum_fir_GUI25.m’ is as follows:

1. run the program ’complex_cepstrum_fir_GUI25.m’ from the directory ’matlab_gui\cepstrum_computation_fir’,
2. using the editable buttons, choose an initial value of 0.85 for the FIR sequence value `alpha` and 100 for for the FIR sequence value N_p,
3. hit the ’FIR 1 Cepstrum’ button to compute and display the spectrum and cepstrums resulting from using FIR Sequence 1,
4. hit the ’FIR 2 Cepstrum’ button to compute and display the spectrum and cepstrums resulting from using FIR Sequence 2,
5. experiment with different choice of values of `alpha` and `Np`,
6. hit the ’Close GUI’ button to terminate the run.

An example of the graphical output obtained from this exercise is shown in Figures 1 for FIR Sequence 1 and Figure 2 for FIR Sequence 2. The format of the graphics panels is the same for both sequences. The upper graphics panel shows the sequence. The second graphics panel shows the log magnitude response of the sequence. The third graphics panel shows the unwrapped and wrapped phase of the sequence. The bottom graphics panel shows the complex cepstrums obtained using the analytical method and the MATLAB routine `cceps`.

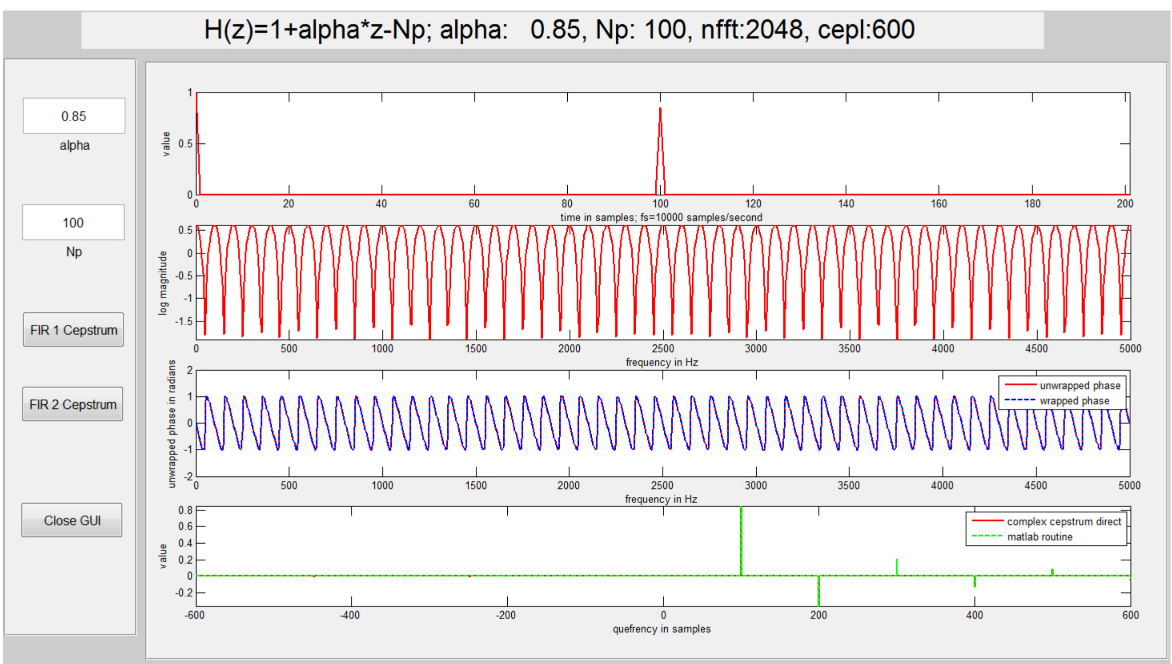

Figure 1: Cepstral analysis results for FIR Sequence 1. The upper panel shows the waveform for FIT Sequence 1; the second graphics panels shows the log magnitude response of FIR Sequence 1; the bottom graphics panel shows the complex cepstrums of Sequence 1, computed using the analytical formula and using the MATLAB routine, `cceps`.

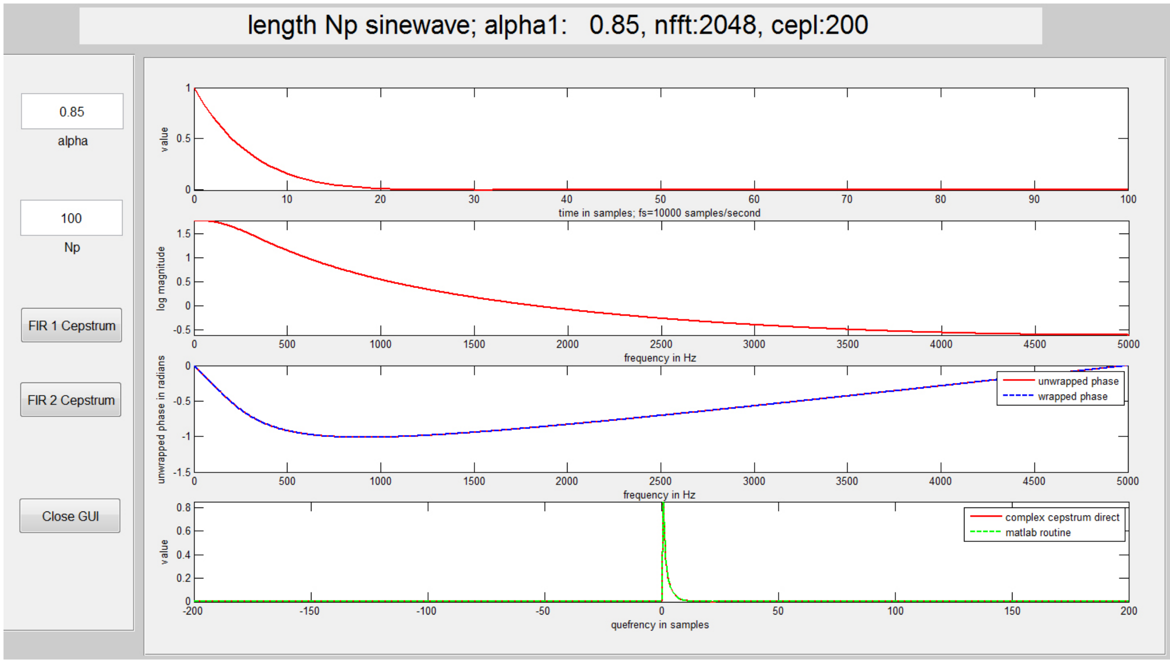

Figure 2: Cepstral analysis results for FIR Sequence 2. The upper panel shows the waveform for FIT Sequence 2; the second graphics panels shows the log magnitude response of FIR Sequence 2; the bottom graphics panel shows the complex cepstrums of Sequence 2, computed using the analytical formula and using the MATLAB routine, `cceps`.

Complex Cepstrum Computation Examples – Issues for Experimentation

1. run the scripted exercise above, and answer the following questions related just to sequence FIR 1:
   - what is the spacing (in samples) between the two impulses in the time domain?
   - what are the approximate locations of the roots of the sequence?
   - why is the log magnitude response of the sequence absolutely flat at the spectral peaks?
   - why are the unwrapped and the wrapped phase functions virtually identical; i.e., no phase wrapping to be compensated by a phase unwrapping routine?
   - what is the form of the complex cepstrum for the sequence?
   - what parameter determines the amplitude of the cepstral peaks?
   - what parameter determines the spacing of the cepstral peaks?
   - why is there virtually no aliasing of the cepstral sequence?
2. the following questions relate just to sequence FIR 1:
   - what happens to the waveform plot, the log magnitude spectrum, the phase (both wrapped and unwrapped), and the complex cepstrum when the parameter N_p is changed from 100 to 50?
   - what happens to the waveform plot, the log magnitude spectrum, the phase (both wrapped and unwrapped), and the complex cepstrum when the parameter N_p is changed from 100 to 200?
3. the following questions relate just to sequence FIR 2:
   - what is the shape of sequence FIR 2 for the given values of N_p and α?

- what signal processing phenomenon explains the shape of the log magnitude response and the phase response? (Recall that $y[n]$ is a product of two functions.)
- how can you explain the shape of the complex cepstrum for this sequence?

4. the following questions relate just to sequence FIR 2:

   - what happens to the waveform plot, the log magnitude spectrum, the phase (both wrapped and unwrapped), and the complex cepstrum when the parameter α changes from 0.85 to 0.999?
   - what happens to the waveform plot, the log magnitude spectrum, the phase (both wrapped and unwrapped), and the complex cepstrum when the parameter α changes from 0.85 to 0.1?