2.4 MATLAB Exercise – Rosenberg Glottal Pulse

Program Directory: `matlab_gui\glottal_pulse`
Program Name: `glottal_pulse_GUI25.m`
GUI data file: `glottal_pulse.mat`
Callbacks file: `Callbacks_glottal_pulse_GUI25.m`
TADSP: Section 5.1, pp. 196-198

This MATLAB exercise computes and plots the discrete-time Rosenberg glottal pulse approximation in both the time domain and the frequency domain, in order to illustrate its impact on the overall spectral level of a frame of a vowel speech signal.

Rosenberg Glottal Pulse – Theory of Operation

The continuous-time glottal pulse is referred to in the textbook as either $u_G(t)$, or $g_c(t)$, and the discrete-time glottal pulse is referred to as either $u_G[n]$, or $g[n] = g_c(nT)$ where T is the sampling period of the digital system.

The form for the continuous-time Rosenberg glottal pulse approximation is:

$$u_G(t) = g_c(t) = \begin{cases} 0.5[1 - \cos(2\pi t/(2T_1))] & 0 \le t \le T_1 \\ \cos(2\pi(t - T_1)/(4T_2)) & T_1 < t \le T_1 + T_2 \end{cases} \tag{1}$$

where T_1 and T_2 are the parameters for the glottal opening and glottal closing durations. By varying T_1 and T_2, different glottal pulse duty cycles can be modeled and approximated.

The form for the discrete-time Rosenberg glottal pulse approximation is:

$$u_G[n] = g[n] = g_c(nT) = \begin{cases} \frac{1}{2}[1 - \cos(\pi n/N_1)] & 0 \le n \le N_1 \\ \cos(\pi(n - N_1)/(2N_2)) & N_1 \le n \le N_1 + N_2 \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

where $N_1 = T_1/T$ and $N_2 = T_2/T$, i.e., the discrete time Rosenberg glottal pulse approximation's temporal and spectral characteristics are dependent on both the opening and closing duty cycles and the sampling period, T. We can also make the glottal pulse characteristics dependent on the pitch period by making T_1 and T_2 be percentages of the current pitch period, rather than absolute durations of the opening and closing phases of the glottal pulse cycle. In this case we define the parameters N_p as the pitch period, $\alpha_1 = N_1/N_p$ as the glottal pulse opening phase percentage, and $\alpha_2 = N_2/N_p$ as the glottal pulse closing phase percentage.

Rosenberg Glottal Pulse – GUI Design

The GUI for this exercise consists of two panels, 5 graphics panels, 1 title box and 9 buttons. The functionality of the two panels is:

1. one panel for the graphics display,
2. one panel for parameters related to specifying parameters of the glottal pulse model, and for running the program.

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

1. the Rosenberg glottal pulse in the time domain (upper left hand panel),
2. the Rosenberg glottal pulse log magnitude spectrum (lower left hand panel),
3. a periodic impulse train with user-specified period (used to excite the vocal tract impulse response convolved with glottal pulse) (middle right hand panel),

4. a periodic glottal pulse train (used to excite the vocal tract impulse response),
5. synthetic vowel sequence excited by a periodic impulse train convolved with a glottal pulse (lower right hand panel).

The title box displays information about the glottal pulse parameters including pulse period (in samples), and pulse onset (`alpha1`) and pulse offset (`alpha2`), both as percentages of the glottal period. The functionality of the 9 buttons is:

1. an editable button that displays the value of `alpha1`, the glottal opening as a percentage of the periodicity period of the glottal pulse stream,
2. an editable button that displays the value of `alpha2`, the glottal closing as a percentage of the periodicity period of the glottal pulse stream,
3. an editable button that displays the excitation signal pitch period (in samples) at a sampling rate of $f_s = 10000$ Hz,
4. a popupmenu button that allows the user to select a vowel sound which is to be synthesized using the periodic glottal pulse train and the vowel formants for the selected vowel sound,
5. a pushbutton to generate the excitation signal for a synthetic vowel sound using the Rosenberg pulse as the glottal approximation, and using the designated vowel impulse response to generate the vowel sound,
6. a pushbutton to play the sequence of periodic impulses,
7. a pushbutton to play the sequence of glottal pulses,
8. a pushbutton to play the synthetic vowel excited with glottal pulses based on the Rosenberg pulse,
9. a pushbutton to close the GUI.

Rosenberg Glottal Pulse – Scripted Run

A scripted run of the program 'glottal_pulse_GUI25.m' is as follows:

1. run the program 'glottal_pulse_GUI25.m' from the directory 'matlab_gui\glottal_pulse',
2. using the set of editable buttons, set values for the glottal pulse parameters, namely `alpha1` (default is 25% of the pitch period), `alpha2` (default is 10% of the pitch period), and pitch period (default is 100 samples at a sampling rate of $f_s = 10000$ samples per second), and the vowel sound used with the glottal pulse, where the choice of vowels include the 10 vowel sounds [IY, IH, EH, AE, AH, AA, AO, UH, UW, ER].
3. hit the 'Generate Excitation Signal' button to compute the Rosenberg glottal pulse and to plot the time (upper left graphics panel) and frequency (lower left graphics panel) characteristics of the resulting glottal pulse; the button callback code also generates a periodic train of impulses (with period designated by the parameter `pitch period`), a periodic sequence of glottal pulses (obtained by convolving the glottal pulse by the periodic impulse train), and a periodic sequence of vowel impulse responses (obtained by convolving the selectedvowel impulse response with the periodic sequence of glottal pulses),
4. hit the 'Play Periodic Impulses' button to play out a periodic sequence of impulses at the pitch period,
5. hit the 'Play Glottal Pulses' button to play out the periodic sequence of Rosenberg pulses,
6. hit the 'Play Vowel Excited With Glottal Pulses' button to play out the synthetic vowel created by exciting the vowel impulse response with the periodic glottal pulse sequence,

7. experiment with different values of the glottal pulse parameters, and with different vowel sounds to get a sense of the role of the glottal pulse shape in eliminating the buzzy sound of a periodic impulse train excitation, and in making the vowel sound more natural,

8. hit the 'Close GUI' button to terminate the run.

An example of the graphical output obtained from this exercise using the glottal pulse parameters of alpha1=25, alpha2=10, period=100 samples at $f_s = 10000$ Hz is shown in Figure 1.

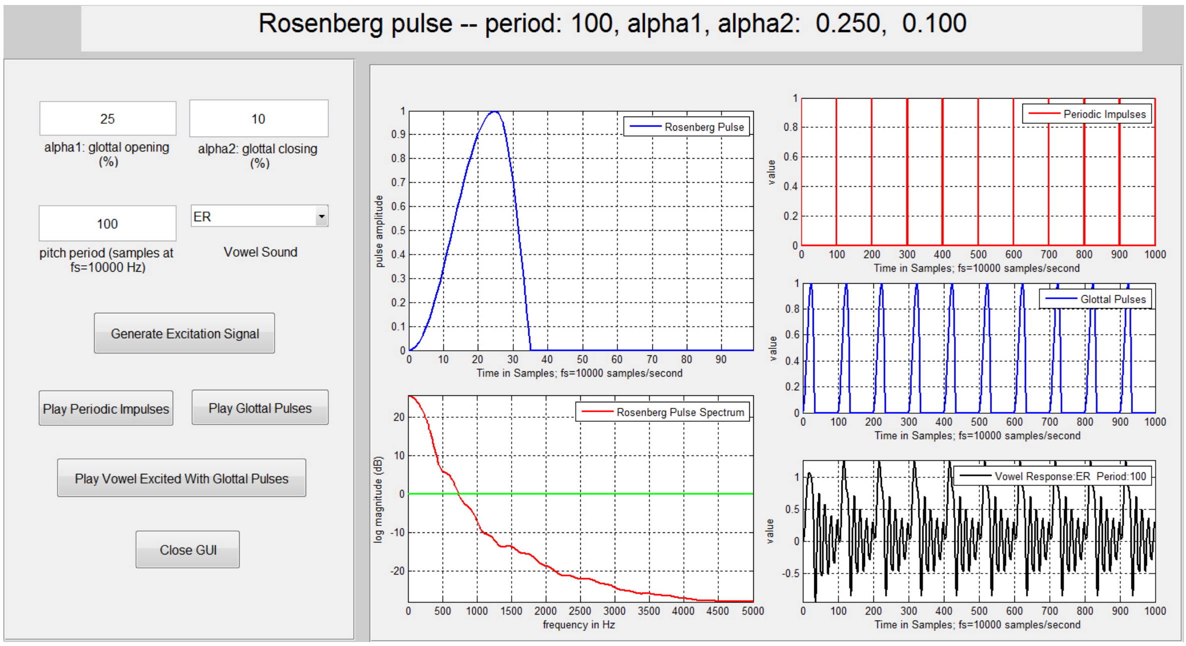

Figure 1: Glottal pulse time response (upper left panel) and log magnitude frequency response (lower left panel) using a Rosenberg pulse with alpha1=25, alpha2=10 and period=100 samples at a sampling rate of fs=10,000 samples per second. The plot also shows the periodic impulse train (upper right panel), the periodic glottal pulse train (middle right panel), and the periodic vowel response (bottom right panel) for the periodic synthetic vowel ER

Rosenberg Glottal Pulse – Issues for Experimentation

1. run the scripted exercise above, and answer the following:

   - what percentage of the pitch period is the glottal opening for the Rosenberg glottal pulse?
   - what percentage of the pitch period is the glottal closing for the Rosenberg glottal pulse?
   - what is the pitch frequency for the default pitch period and sampling rate?
   - what is the ratio (in dB) of the peak log magnitude spectral response (of the Rosenberg pulse), i.e., at $f = 0$, to the minimum log magnitude spectral response (at frequency $f_s/2 = 5000$ Hz)?
   - comment on the quality of the resulting vowel sound (for the IY default vowel)
   - using the AA vowel, systematically vary the pitch period, the glottal opening and closing parameters, and then listen to the resulting synthetic vowel signal. Describe the effects of each of the parameters on the sound of the resulting synthetic vowel.

2. change the 'Vowel Sound' to each of the 10 vowels and repeat the exercise

- how close does the synthetic vowel match the intelligibility and naturalness of a human-produced vowel sound for each of the ten vowels?

3. by varying the glottal opening and glottal closing cycle parameters, different Rosenberg glottal pulses can be created, with differing amounts of high and low frequency gain (or loss);

    - change the glottal opening and closing parameters and see what range of high-frequency loss (relative to the spectral level at 0 frequency) can be obtained