Signal Processing First
Lab 12: Two Convolution GUIs

The lab report for this lab will be **informal.** Discuss your results from section 4.

Pre-Lab and Warm-Up: You should read at least the Pre-Lab and Warm-up sections of this lab assignment and go over all exercises in the Pre-Lab section before going to your assigned lab session.

Verification: The Warm-up section of each lab must be completed **during your assigned Lab time** and the steps marked *Instructor Verification* must also be signed off **during the lab time**. One of the laboratory instructors must verify the appropriate steps by signing on the **Instructor Verification** line. When you have completed a step that requires verification, simply demonstrate the step to the TA or instructor. Turn in the completed verification sheet to your TA when you leave the lab.

Lab Report: It is only necessary to turn in a report on Section 4 with graphs and explanations. You are asked to **label** the axes of your plots and include a title for every plot. In order to keep track of plots, include your plot *inlined* within your report. If you are unsure about what is expected, ask the TA who will grade your report.

1 Introduction

This lab concentrates on the use of two MATLAB GUIs for convolution.

1. **dconvdemo:** GUI for discrete-time convolution. This is exactly the same as the MATLAB functions `conv()` and `firfilt()` used to implement FIR filters.

2. **cconvdemo:** GUI for continuous-time convolution.

CD-ROM
Chap 5 Demos dconvdemo

CD-ROM
Chap 9 Demos cconvdemo

Each one of these demos illustrates an important point about the behavior of a linear, time-invariant (LTI) system. They also provide a convenient way to visualize the output of a LTI system.

Both of these demos are on the *SP First CDROM* . If you are working on your own machine, you must download the ZIP files for each (dconvdemo is in Chapter 5 Demos, and cconvdemo in in Chapter 9 Demos) and install them. Each one installs as a directory containing a number of files along with a `private` sub-directory.

2 Pre-Lab: Run the GUIs

The first objective of this lab is to demonstrate usage of two convolution GUIs.

2.1 Discrete-Time Convolution Demo

In this demo, you can select an input signal $x[n]$, as well as the impulse response of the filter $h[n]$. Then the demo shows the "flipping and shifting" used when a convolution is computed. This corresponds to the sliding window of the FIR filter. Figure 1 shows the interface for the `dconvdemo` GUI.
In the pre-Lab, you should perform the following steps with the `dconvdemo` GUI.

(a) Set the input to a finite-length pulse: $x[n] = 2\,\{u[n] - u[n-10]\}$.

(b) Set the filter's impulse response to obtain a five-point averager.

McClellan, Schafer, and Yoder, *Signal Processing First*, ISBN 0-13-065562-7.

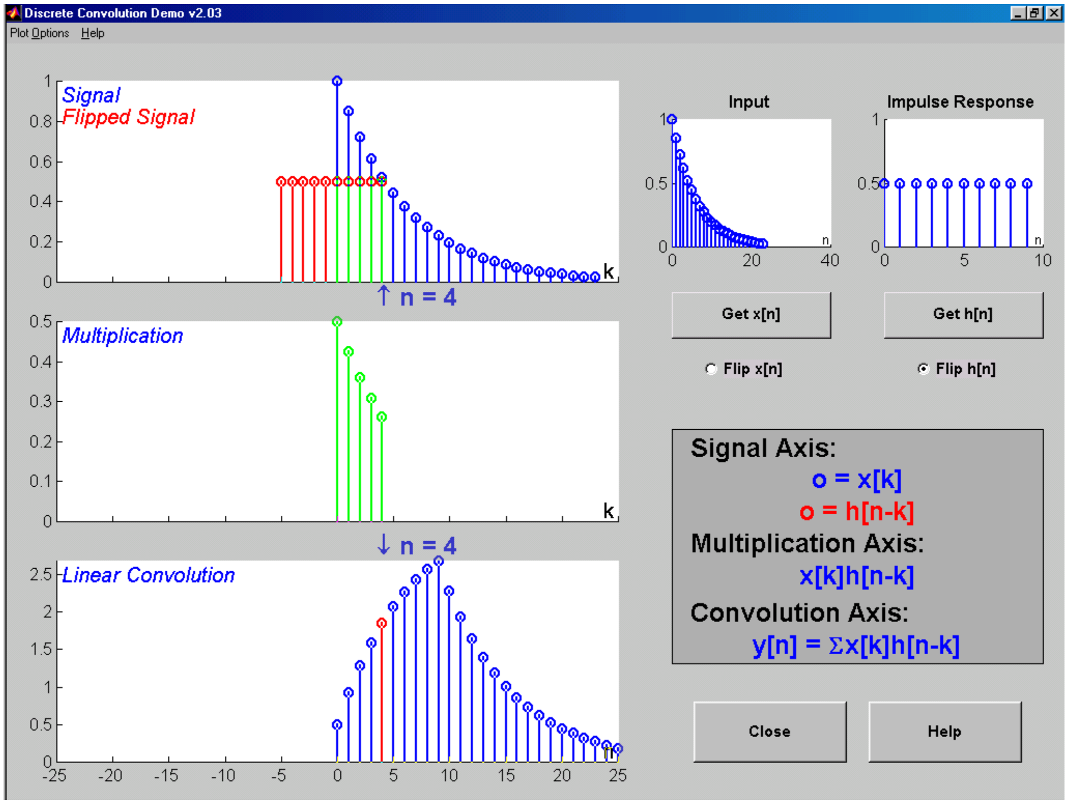

Figure 1: Interface for discrete-time convolution GUI.

(c) Use the GUI to produce the output signal.

(d) When you move the mouse pointer over the index “n” below the signal plot and do a click-hold, you will get a *hand tool* that allows you to move the “n”-pointer. By moving the pointer horizontally you can observe the sliding window action of convolution. You can even move the index beyond the limits of the window and the plot will scroll over to align with “n.”

(e) Set the filter’s impulse response to a length-10 averager, i.e., $h[n] = 0.1\{u[n] - u[n-10]\}$. Use the GUI to produce the output signal.

(f) Set the filter’s impulse response to a shifted impulse, i.e., $h[n] = \delta[n-3]$. Use the GUI to produce the output signal.

(g) Compare the outputs from parts (c), (e) and (f). Notice the different shapes (triangle, rectangle or trapezoid), the maximum values, and the different lengths of the outputs.

2.2 Continuous-Time Convolution Demo

In this demo, you can select an input signal $x(t)$, as well as the impulse response of an **ANALOG** filter $h(t)$. Then the demo shows the “flipping and shifting” used when a convolution integral is performed. Figure 2 shows the interface for the `cconvdemo` GUI.
In the Pre-Lab, you should perform the following steps with the `cconvdemo` GUI.

(a) Set the input to a 4-second pulse $x(t) = u(t) - u(t-4)$.

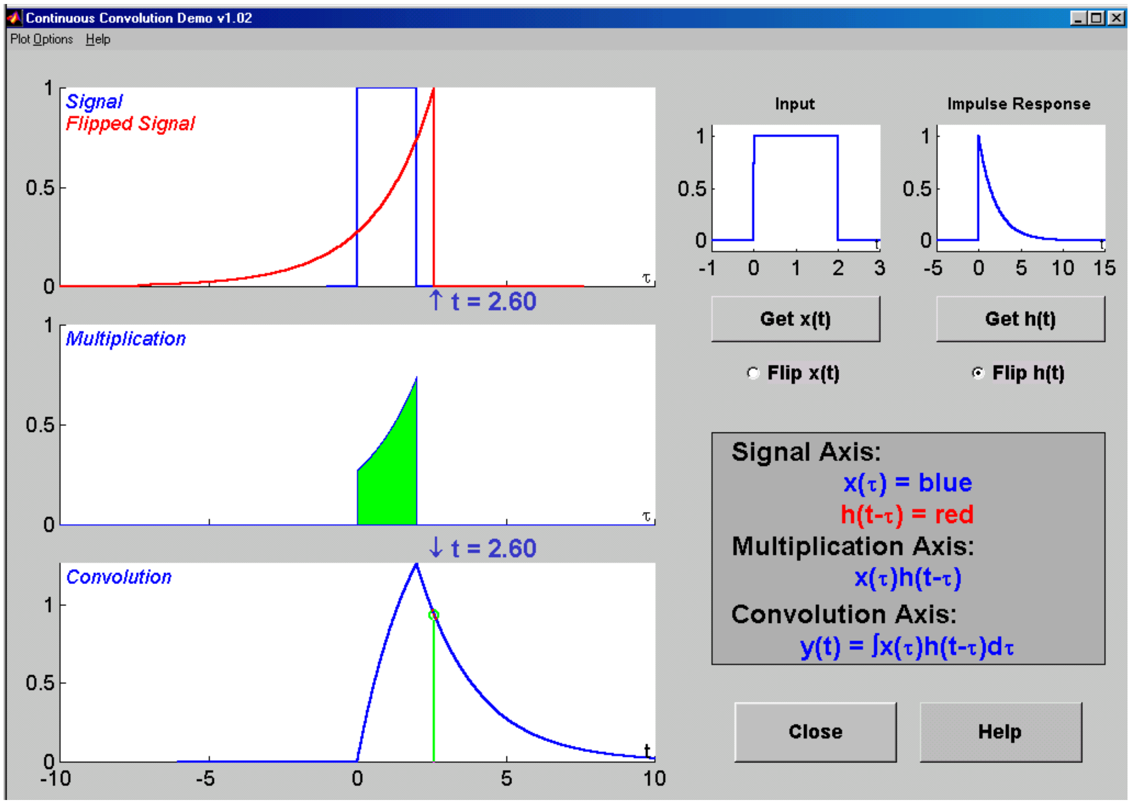

Figure 2: Interface for continuous-time convolution GUI.

(b) Set the filter's impulse response to a 2-second pulse with amplitude 0.5, i.e., $h(t) = 0.5\{u(t) - u(t-2)\}$.

(c) Use the GUI to produce the output signal. Use the *sliding hand tool* to grab the time marker and move it to produce the flip-and-slide effect of convolution.

(d) Set the filter's impulse response to a 4-second pulse with amplitude 0.25, i.e., $h(t) = 0.25\{u(t) - u(t-4)\}$. Use the GUI to produce the output signal.

(e) Set the filter's impulse response to a shifted impulse, i.e., $h(t) = \delta(t-3)$. Use the GUI to produce the output signal.

(f) Compare the outputs from parts (c), (d) and (e). Notice the different shapes (triangle, rectangle or trapezoid), the maximum values, and the different lengths of the outputs.

3 Warm-up: Run the GUIs

The objective of the warm-up in this lab is to use the two convolution GUIs to solve problems (some of which may be assigned homework problems). If you are working on your own machine, you must download the ZIP files for each (dconvdemo is in Chapter 5 Demos, and cconvdemo in in Chapter 9 Demos) and install them. Each one installs as a directory containing a number of files along with a `private` sub-directory.

3.1 Continuous-Time Convolution GUI

In the warm-up, you should perform the following steps with the `cconvdemo` GUI.

(a) Set the input to an exponential: $x(t) = e^{-0.25t}\,\{u(t) - u(t-6)\}$.

(b) Set the filter's impulse response to a different exponential: $h(t) = e^{-t}\,\{u(t+1) - u(t-5)\}$.

(c) Use the GUI to produce a plot of the output signal. Use the *sliding hand tool* to grab the time marker and move it to produce the flip-and-slide effect of convolution. Note: if you move the hand tool past the end of the plot, the plot will automatically scroll in that direction.

(d) Usually, in the case of two finite-duration signals like in parts (a) and (b), the convolution integral must be evaluated in 5 different regions: no overlap (on the left side), partial overlap (on the left side), complete overlap, partial overlap (on the right side), and no overlap (on the right side). In this case, there are only 4 regions. Why?

(e) Set up the convolution integral for the second region. This is the case of partial overlap (on the left side). In addition, determine the boundaries (in secs) of the second region, i.e., the starting and ending times of region #2. Use the flip and slide interpretation of convolution along with the GUI to help answer this question.

Instructor Verification (separate page)

3.2 Discrete Convolution GUI

In the warm-up, you should perform the following steps with the `dconvdemo` GUI.

(a) Set the input to a finite-length sinusoid: $x[n] = 2\cos(2\pi(n-2)/3)\,(u[n-2] - u[n-12])$.

(b) Set the filter's impulse response to obtain a 3-point averager.

(c) Use the GUI to produce the output signal.

(d) Explain why the output has five different regions and why the output is zero in three of the five.

Instructor Verification (separate page)

4 Lab Exercises

In each of the following exercises, you should make a screen shot of the final picture produced by the GUI to validate that you were able to do the implementation. In all cases, you will have to do some mathematical calculations to verify that the MATLAB GUI result is correct.

4.1 Continuous-Time Convolution

In this section, use the continuous-time convolution GUI, `cconvdemo`, to do the following:

(a) Set the input to an exponential: $x(t) = e^{-0.25t}\,\{u(t) - u(t-6)\}$.

(b) Set the filter's impulse response to a different exponential: $h(t) = e^{-t}\,\{u(t+1) - u(t-5)\}$.

(c) Use the GUI to produce a plot of the output signal.

(d) Usually the convolution integral must be evaluated in 5 different regions: no overlap (on the left side), partial overlap (on the left side), complete overlap, partial overlap (on the right side), and no overlap (on the right side). In this case, there are only 4 regions. Determine the boundaries of each region, i.e., the starting and ending times in secs.

(e) Determine the mathematical formula for the convolution in each of the four regions. Use the GUI to help in setting up the integrals, but evaluate the integrals by hand.

4.2 Continuous-Time Convolution Again

(a) Find the output of an analog filter whose impulse response is

$$h(t) = u(t+3) - u(t)$$

when the input is

$$x(t) = 2\cos(2\pi(t-2)/3)\,\{u(t-2) - u(t-12)\}$$

(b) Use the GUI to determine the length of the output signal and the boundaries of the five regions of the convolution.
Note: the regions of partial overlap would be called *transient regions* while the region of complete overlap would be the *steady state region.*

(c) Perform the mathematics of the convolution integral to get the exact analytic form of the output signal and verify that the GUI is correct. Also verify that the duration of the output signal is correct.

4.3 Discrete-Time Convolution

Use the discrete-time convolution GUI, `dconvdemo`, to do the following:

(a) Find the output of a digital filter whose impulse response is

$$h[n] = u[n+3] - u[n]$$

when the input is

$$x[n] = 2\cos(2\pi(n-2)/3)\{u[n-2] - u[n-12]\}$$

(b) Use the GUI to determine the length of the output signal and notice that you can see five regions just like for the continuous-time convolution.
Note: the regions of partial overlap would be called *transient regions* while the region of complete overlap would be the *steady-state region.*

(c) Use numerical convolution to get the exact values of the output signal for each of the five regions. Thus, you will verify that the GUI is correct. Also verify that the duration of the output signal is correct.

(d) Discuss the relationship between this output and the continuous-time output signal in Section 4.2. Point out similarities and differences.

Lab 12
INSTRUCTOR VERIFICATION PAGE

For each verification, be prepared to explain your answer and respond to other related questions that the lab TA's or professors might ask. Turn this page in at the end of your lab period.

Name: ____ Date of Lab: __________

Part 3.1: Demonstrate that you can run the continuous-time convolution demo. Explain how to find the FOUR regions for this convolution integral. In the space below, write the specific convolution integral that would be performed for these specific exponential signals in REGION #2. Make sure that the limits of integration are correct.

Verified:____________________ Date/Time:__________

$$y(t) = \int \qquad\qquad\qquad \text{for} \qquad \leq t \leq$$

Part 3.2: Demonstrate that you can run the discrete-time convolution demo. Explain why the output is zero in three of the five regions identified for the output signal.

Verified:____________________ Date/Time:__________