

BIOE 198MI Biomedical Data Analysis. Spring Semester 2018.

Lab6: Signal processing and filter design

Problem Statement: In this lab, we are considering the problem of designing a window-based digital filter (lowpass, highpass, bandpass) using MATLAB function `fir1`.

Section 1

Load the MATLAB built-in audio file 'chirp'. look at the workspace and find out what's in the 'chirp' file.

Q1: What is the sampling frequency(F_s) of the data? What is the meaning of sampling? Based on y and F_s , how can we compute the time duration of y ?

Section 2

Use MATLAB functions to record 3 seconds of your own voice data.

step 1: First create an audio block with specific sampling frequency, number of bits per sample and number of channels.

```
recObj = audiorecorder(Fs,NumBit,NumChannel);
```

step 2: Use function 'recordblocking' to record certain time of voice data

```
recordblocking(recObj, Time);
```

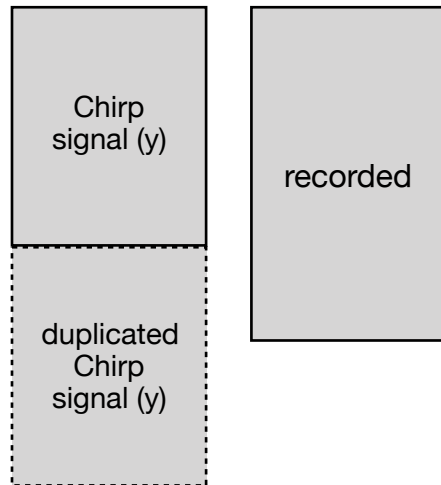
step3: Use function 'getaudiodata' to store the audio signal into an array

Q2: play the recorded audio signal and describe the effect of NumBit(bit depth). NumBit can be 8, 16 or 24.

Section 3

Combine the chirp and recorded data together.

Notice that the chirp data 'y' is a shorter variable than our recorded data, therefore we can not directly add them together.



Duplicate the chirp signal first,

option 1: `chirp = [y ; y]`

Q3: Why do we use a semicolon?

option 2: `chirp = repmat(y,2,1);`

Then add same amount of elements together to create the combined signal.

```
combined = chirp(1:length(recorded))+recorded;
```

Q4: What if in Section 2 we recorded 4 seconds of audio signal instead of 3 seconds, how should we manipulate the chirp signal?

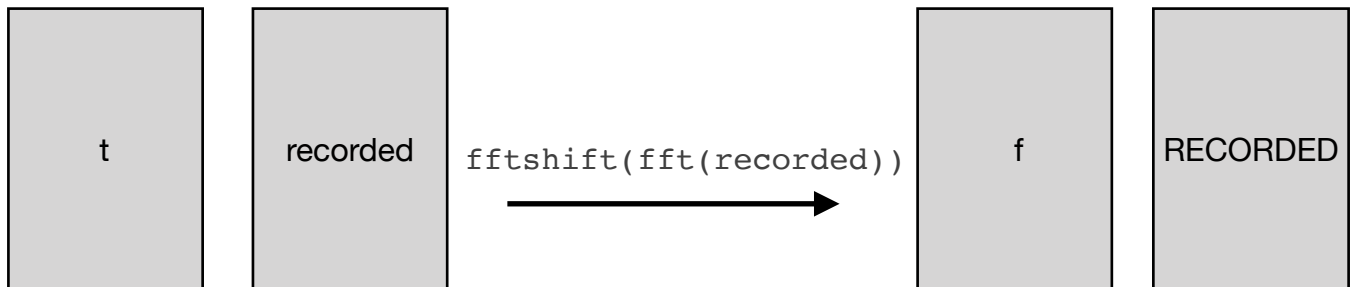
Section 4

Play the recorded signal, the chirp signal and their combination. Plot all three signals in the time domain. In time domain, is there a way to separate each signal(the recorded and chirp signal) from the combined signal?

Obviously no. Because both signals are on top of each other. In other words, they're overlapped with each other. That's why we need to introduce the Fourier transform.

Generally speaking, Fourier transform transfers a time domain signal into frequency domain, which allows you to tell what frequencies are present in your signal.

The Fourier transforms (Matlab 1D Fourier transform function 'fft') take a signal and express it in terms of the frequencies of the waves.



Q5: What is Nyquist frequency? What does the function `fftshift` do?

We only plot positive side of the frequency spectrum (0 to Nyquist frequency).

Look at the frequency spectrum of the signals (figure 2) and find out which one has higher frequency.

If we want to separate the chirp and recorded data in frequency domain, what is the cutoff frequency we should use?

%% Section 5

Design a window-based lowpass filter to filter out the chirp sound.

```
firl(Order, CutOff/Nyquist, 'low');
```

To use the MATLAB built-in window filter, we need at least 3 inputs, the order of the filter, cutoff ratio, and filter type(low pass, high pass or bandpass).

The cutoff ratio can be calculated with equation

$$\text{Cutoff ratio} = \frac{\text{Cutoff frequency}}{\text{Nyquist frequency}} = \frac{\text{Cutoff frequency}}{\text{Sampling frequency}/2}$$

Q6: Use 10, 20, 50, 100, 500 as order number and describe the magnitude response of the filter.

%% Section 6

Design a window-based highpass filter ('bhi') to filter out the recorded sound.

Signal processing and filter design assignment

You are given a MATLAB generated chord signal 'chord_sig.mat'; The variable sig contains multiple pitches in it. However, they are all summed together in time domain.

- Use what you learned in lab to separate each pitch. Describe how you extract each note from the signal and justify your answer.
- Create a small piece of audio song, for example 'Twinkle, Twinkle, Little Star', 'Mary had a little lamb', 'The wheels on the bus', etc. **After creating the song**, use MATLAB function 'audiowrite' to export the song. (eg. `audiowrite('TwinkleStar.wav', song, Fs)`)
- Answer all the in-lab questions

For your reference, here is a table of the frequencies for several notes.

Note		Frequency (Hz)
C ₄ (middle C)	do	262
D ₄	re	294
E ₄	mi	330
F ₄	fa	349
G ₄	so	392
A ₄	la	440
B ₄	ti	494
C ₅		523