Lab 2 - Solution

October 17, 2019

1 Lab 2 - Basic Signals

1.0.1 SOLUTION

This week, the lab will be an assignment to get familar with some basic DSP and audio in Python. Please complete the following problems.

```
In [1]: import numpy as np
        import matplotlib.pyplot as plt
        import IPython.display as ipd
        from scipy import signal

        %matplotlib inline
```

Remember, you can always use python's help function to learn more about any function or module. For example, see below:

```
In [2]: help(np.arange)
```

```
Help on built-in function arange in module numpy.core.multiarray:

arange(...)
    arange([start,] stop[, step,], dtype=None)

    Return evenly spaced values within a given interval.

    Values are generated within the half-open interval ``[start, stop)``
    (in other words, the interval including `start` but excluding `stop`).
    For integer arguments the function is equivalent to the Python built-in
    `range <http://docs.python.org/lib/built-in-funcs.html>`_ function,
    but returns an ndarray rather than a list.

    When using a non-integer step, such as 0.1, the results will often not
    be consistent.  It is better to use ``linspace`` for these cases.

    Parameters
```

```
----------
start : number, optional
    Start of interval.  The interval includes this value.  The default
    start value is 0.
stop : number
    End of interval.  The interval does not include this value, except
    in some cases where `step` is not an integer and floating point
    round-off affects the length of `out`.
step : number, optional
    Spacing between values.  For any output `out`, this is the distance
    between two adjacent values, ``out[i+1] - out[i]``.  The default
    step size is 1.  If `step` is specified as a position argument,
    `start` must also be given.
dtype : dtype
    The type of the output array.  If `dtype` is not given, infer the data
    type from the other input arguments.

Returns
-------
arange : ndarray
    Array of evenly spaced values.

    For floating point arguments, the length of the result is
    ``ceil((stop - start)/step)``.  Because of floating point overflow,
    this rule may result in the last element of `out` being greater
    than `stop`.

See Also
--------
linspace : Evenly spaced numbers with careful handling of endpoints.
ogrid: Arrays of evenly spaced numbers in N-dimensions.
mgrid: Grid-shaped arrays of evenly spaced numbers in N-dimensions.

Examples
--------
>>> np.arange(3)
array([0, 1, 2])
>>> np.arange(3.0)
array([ 0.,  1.,  2.])
>>> np.arange(3,7)
array([3, 4, 5, 6])
>>> np.arange(3,7,2)
array([3, 5])
```

1.1 Problem 1 - Sum of weighted sinusoids

Using the given parameters, create a signal **x** that contains the following sum of sinusoids.

$$x = \sum_{n=1}^{numFreqs} \frac{\cos(2\pi n f_0 t)}{n}$$

Let the sampling rate **fs** be 8000Hz, the duration **dur** be 2 seconds, the fundamental frequency **f0** be 200Hz, and the number of frequencies **numFreqs** be 12. Plot the first 20 milliseconds of the time domain signal. Then plot the magnitude spectrum in the frequency domain from 0Hz to the Nyquist frequency. Finally, listen to your signal.

```
In [3]: fs = 8000
        dur = 2
        f0 = 200
        numFreqs = 12
```

Hint: You may consider using the following functions - np.arange() - np.linspace() - np.cos() - np.dot() - plt.xlim() - plt.plot() - np.fft.fft() - np.fft.fftfreq() - np.absolute() - ipd.Audio()

Also, you can always check the dimensions of an array with np.shape(). You can use np.reshape() to change this shape.

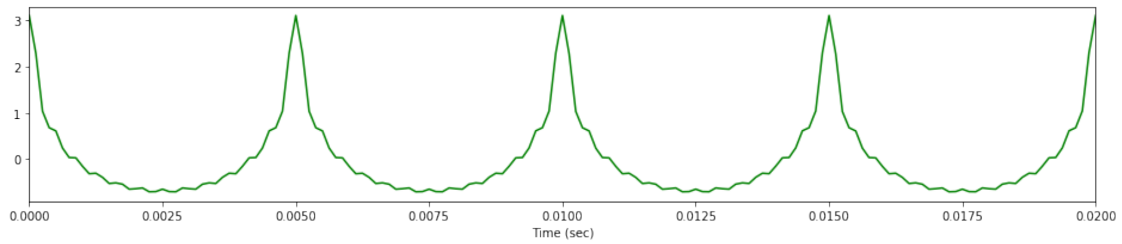
1.2 Your Answer:

```
In [4]: freq = f0*np.arange(1,numFreqs+1)
        k = 1./np.arange(1,numFreqs+1)
        t = np.linspace(0,dur,(dur*fs))

        freq.shape = (numFreqs,1)
        k.shape = (1,numFreqs)
        t.shape = (1,(dur*fs))
```

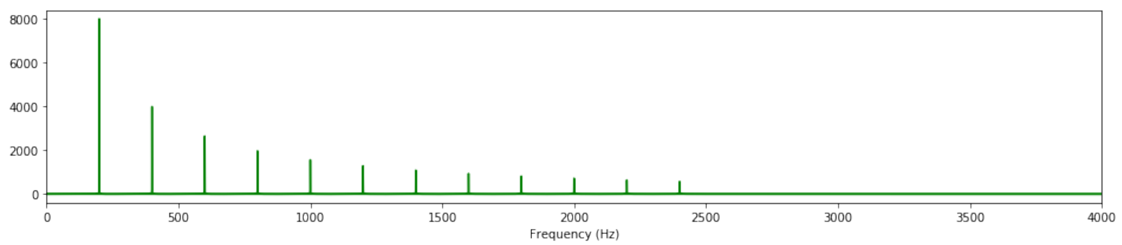
```
In [5]: # Generate matrix of sinusoids
        X = np.cos(2 * np.pi * freq * t)
```

```
In [6]: # Weight by magnitude vector k and sum
        XX = np.dot(k,X)
```

```
In [7]: XX.shape = (16000,)
        t.shape = (16000,)

        plt.figure(figsize = (16,3))
        plt.xlim(0,0.02)
        plt.xlabel("Time (sec)")
        plt.plot(t,XX,"g-");
```




```
In [8]: fftXX = np.absolute(np.fft.fft(XX))
        f = fs * np.fft.fftfreq(len(XX))

        plt.figure(figsize = (16,3))
        plt.xlim(0,fs/2)
        plt.xlabel("Frequency (Hz)")
        plt.plot(f,fftXX,"g-");
```




```
In [9]: ipd.Audio(XX, rate = fs)

Out[9]: <IPython.lib.display.Audio object>
```

1.3 Problem 2 - Chirp signal

Create a linear chirp signal whose frequency starts at **f1** of 50Hz and ends after 5 seconds at **f2** of 2kHz. Reminder: a chirp signal is a sinusoid with a constantly changing frequency.

Use a sampling rate of 8000Hz.

Plot the first 200 ms of the chirp in the time domain. Then plot its magnitude and phase spectra in the frequency domain from 0Hz to the Nyquist frequency. Finally, listen to your chirp signal.

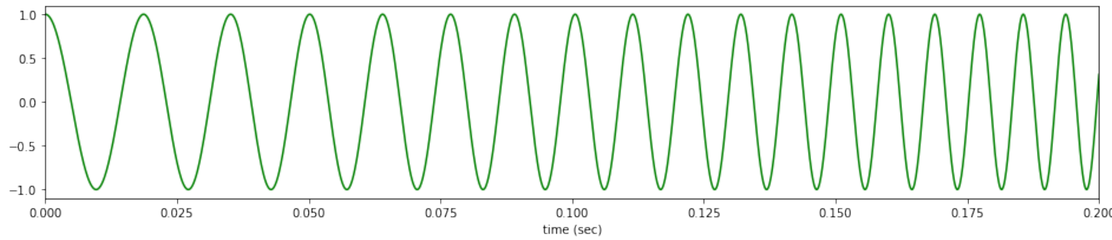
```
In [10]: f1 = 50
         f2 = 2000
         dur = 5
```

Hint: You may consider using the following functions - np.linspace() - signal.chirp() - plt.xlim() - plt.plot() - np.fft.fft() - np.fft.fftfreq() - np.fft.fftshift() - np.absolute() - np.arctan() - ipd.Audio()

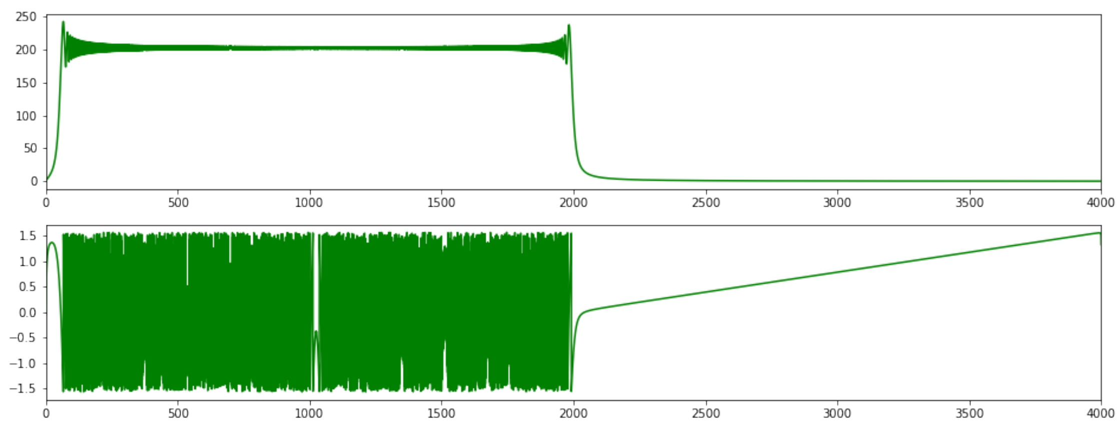
1.4 Your Answer:

In [11]:
```
chirpT = np.linspace(0,dur,(dur*fs))

c = signal.chirp(chirpT, f0=f1, f1=f2, t1=dur, method='linear')
```

In [12]:
```
plt.figure(figsize = (16,3))
plt.xlabel("time (sec)")
plt.xlim(0,0.2)
plt.plot(chirpT, c, "g-");
```



In [13]:
```
Y = np.fft.fftshift(np.fft.fft(c))
magy = np.absolute(Y)
phasey = np.arctan(np.imag(Y)/np.real(Y))
f = fs * np.fft.fftshift(np.fft.fftfreq(len(Y)))

plt.figure(figsize = (16,6))
plt.subplot(211)
plt.xlim(0,fs/2)
plt.plot(f, magy, "g-")
plt.subplot(212)
plt.xlim(0,fs/2)
plt.plot(f, phasey, "g-");
```



```
In [14]: ipd.Audio(c, rate = fs)
```

```
Out[14]: <IPython.lib.display.Audio object>
```