Lab 1 - Solution

September 25, 2019

1 Lab 1 - Audio in Python

In this tutorial, we will synthesize a sine tone from an array of values and plot it. We'll listen to the signal in the notebook and also export it as a WAV file. Finally, we'll import a WAV file and crop it.

1.1 Generating a Sine Tone

First, we need to import **NumPy**, a python package for scientific computing.

```
In [1]: import numpy as np
```

Next, we'll create variables to hold the **frequency**, **duration**, and **sampling rate** of our sine tone. Let's generate a tone at **440 Hz** that lasts **3 seconds** long with a sampling rate of **22050 Hz**.

```
In [2]: freq = 440
        dur = 3.0
        sr = 22050
```

We can make an array of time values, **t**, which contains each point in time that we want a sample. The **np.linspace** function below creates an array of 66,150 evenly spaced numbers ranging from 0 to 3.

```
In [3]: t = np.linspace(0, dur, int(dur * sr), endpoint = False)
```

Since the **t** array is very long, only the first few and last few values are displayed below.

```
In [4]: t

Out[4]: array([0.00000000e+00, 4.53514739e-05, 9.07029478e-05, ...,
               2.99986395e+00, 2.99990930e+00, 2.99995465e+00])
```

To generate a sine tone, at each point in time, we want to plug our current t value into a sine function.

$$x = \sin(2\pi f t)$$

NumPy's **np.sin** function lets us plug an array of time values in and get an array of output values. We'll store the output in a variable called **x**.

```
In [5]: x = np.sin(2 * np.pi * freq * t)
        x
```

```
Out[5]: array([ 0.        ,  0.12505052,  0.24813785, ..., -0.36732959,
               -0.24813785, -0.12505052])
```

Looking at just these few values, it's hard to tell we made a sine wave. Let's visualize it.

1.2 Plotting a Signal

First we need to import **matplotlib.pyplot** for creating plots.

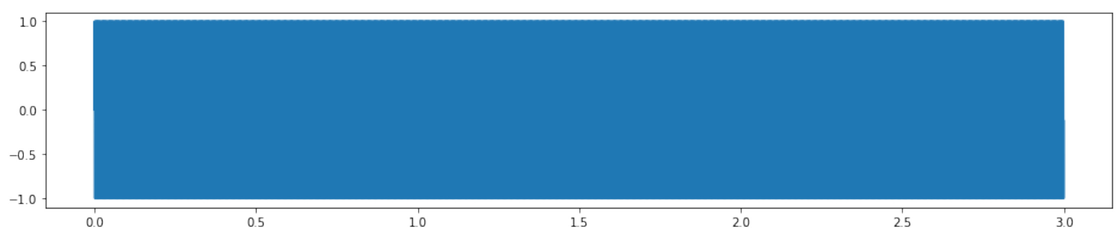
```
In [6]: import matplotlib.pyplot as plt
```

The following line allows plots to be visible within the notebook.

```
In [7]: %matplotlib inline
```

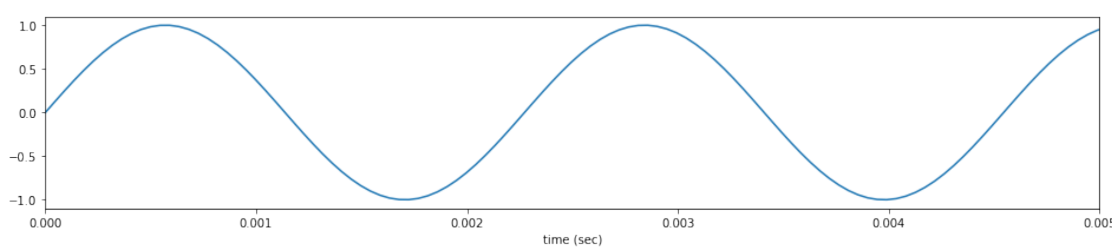
First, the **plt.figure** line below allows us to adjust the size of the figure. Then, we simply call **plt.plot** to plot the signal. The semi colon suppresses output from python.

```
In [8]: plt.figure(figsize = (16,3))
        plt.plot(t,x);
```



This just looks like a blue rectangle since the sine wave oscillates quickly in a short space. To see the sine wave, we'll use **plt.xlim** to crop the plot's range along the x axis. Let's look at just the first **5 milliseconds**. Also we'll label the seconds along the x axis.

```
In [9]: plt.figure(figsize = (16,3))
        plt.xlim(0,0.005)
        plt.xlabel("time (sec)")
        plt.plot(t,x);
```



Now that we've visualized our signal, let'ls listen to it.

1.3 Listening to an Audio Signal

Using **IPython.display.Audio**, we can listen to an audio signal from a NumPy array. Let's import IPython display.

```
In [10]: import IPython.display as ipd
```

Now we just need to give the **ipd.Audio** function our signal **x** and its sampling rate **sr**, and we can play the sound right in the notebook.

```
In [11]: ipd.Audio(x,rate = sr)

Out[11]: <IPython.lib.display.Audio object>
```

1.4 Exporting Audio

In addition to listening to a signal in the notebook, we can export it as a WAV file using the **Librosa** audio signal processing library. Let's import it.

```
In [12]: import librosa
```

To export an array as a sound file we can use the **librosa.output.write_wav** function. Simply pass it the signal, its sampling rate, and the desired filename.

```
In [13]: librosa.output.write_wav('sine_440_3s.wav', x, sr)
```

Now, there should be an audio file called **'sine_440_3s.wav'** saved in the same directory as this notebook.

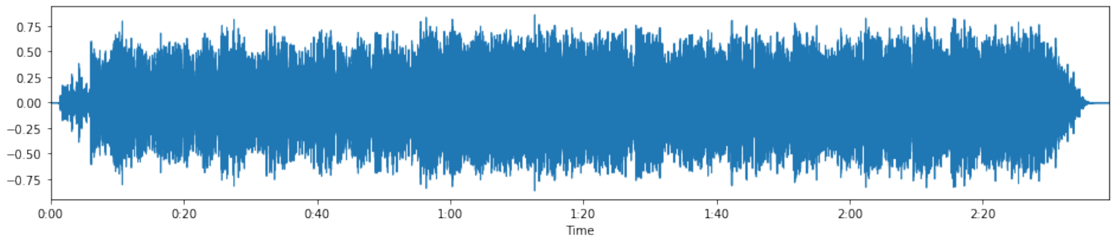
1.5 Importing Audio

We can also *import* audio from a WAV file into a numpy array using **Librosa.** Let's import the audio file **taxman.wav**, which should be saved in the same directory as this notebook. The **librosa.load** function will return the audio signal as an array, **y**, as well as its sampling rate.

```
In [14]: y, sr_y = librosa.load('taxman.wav')
```

Let's visualize the signal **y** and listen to it. This time we'll plot with **librosa.display.waveplot**, which is useful for cleanly displaying the amplitude envelope of time domain audio signals.

```
In [15]: import librosa.display
         plt.figure(figsize=(16, 3))
         librosa.display.waveplot(y,sr_y);
```




```
In [16]: ipd.Audio(y,rate = sr_y)

Out[16]: <IPython.lib.display.Audio object>
```

1.6 Cropping an Audio Signal

Finally, let's edit this audio signal by cropping a **5 second** clip of the beginning. We'll compute the clip length in samples using the sampling rate.

```
In [17]: clip_length = 5 * sr_y
         clip_length

Out[17]: 110250
```

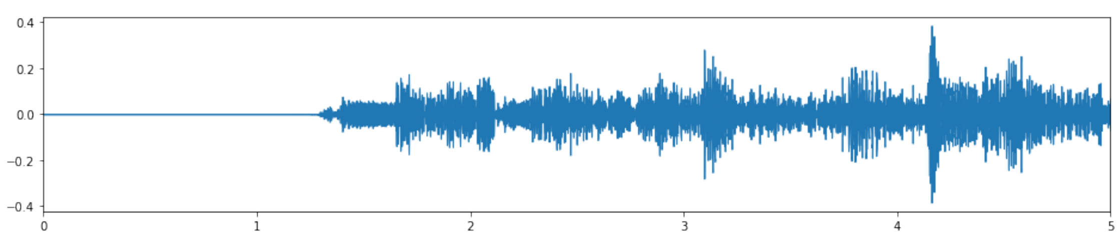
We can use simple array slicing to do the cropping.

```
In [18]: clip_y = y[:110250]
         len(clip_y)

Out[18]: 110250
```

Let's **plot**, **listen to**, and **export** our clip.

```
In [19]: # plot
         plt.figure(figsize=(16, 3))
         librosa.display.waveplot(clip_y,sr_y);
```



In [21]:
```
# listen
ipd.Audio(clip_y,rate = sr_y)
```

Out[21]:
```
<IPython.lib.display.Audio object>
```

In [22]:
```
# export
librosa.output.write_wav('taxman_5s.wav', clip_y, sr_y)
```