Adding noise to audio

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This article discusses how to add noise to audio data (or any other data). This can be important for many applications such as evaluating the performance of machine learning models.

For example a deep learning model which classifies audio data can be affected by noise. So we can alter the original signal samples with noises of varying signal to noise ratios and evaluate the performance of the model under these noisy conditions.

. . .

To read audio .wav into an array from file we can use the code below. I have used python for examples shown here
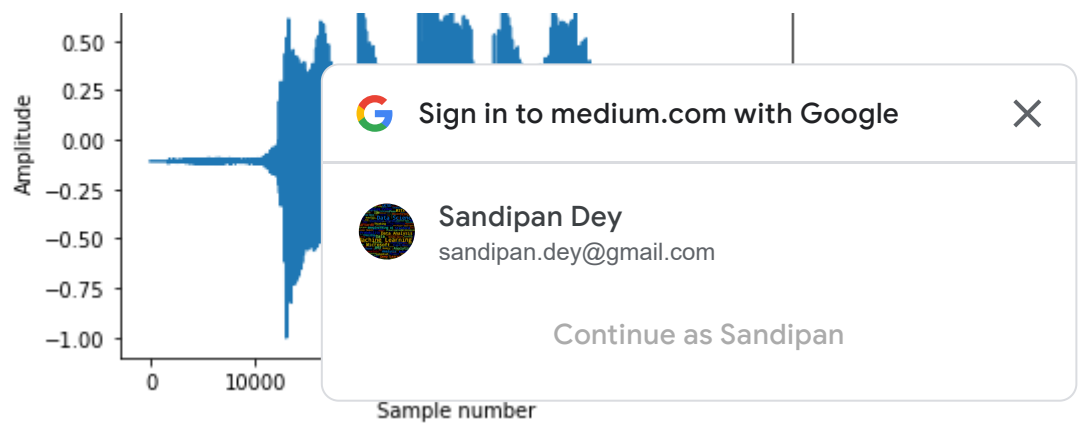
```
import librosa

signal, sr = librosa.load("path/to/audio.wav")
```

To obtain a plot of the signal I used for these experiments (me saying "Leave my dog alone!")

```
import matplotlib.pyplot as plt

plt.plot(signal)
```

Plot of the signal

Signal to Noise Ratio

Signal to noise ratio (SNR) can be defined as follows :

Definition of SNR

where RMS_signal is the RMS value of signal and RMS_noise is that of noise. log is the logarithm of 10

we can use the code below to calculate RMS value of a signal

```
import numpy as np

RMS=math.sqrt(np.mean(signal**2))
```

Now its the time to add some noise to the signal

We describe 2 types of noises that can be added to audio data

- Additive White Gaussian Noise (AWGN)

- Real world noises

Please refer to the following GitHub repo for the code

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Additive White Gaussian Noise (AWGN)

This kind of noise can be added (arithmetic element-wise addition) to the signal. Also its mean value is zero (randomly sampled from a Gaussian distribution with mean value of zero. standard deviation can vary). It contains all the frequency components in an equal manner (hence "white" noise).

AWGN is important because it is easier to model for analytical analyzes and it's easier to generate. But it may not represent realistic noise conditions for some applications.

From the code in the GitHub repo, we can use the function *get_white_noise* to generate AWGN of desired SNR. This has a mean value of approximately 0.0

How to generate AWGN

From SNR definition equation, we can obtain

$$RMS_{noise} = \sqrt{\frac{RMS^2_{signal}}{10^{SNR/10}}}$$

Required RMS value of noise

Here RMS_required is the required RMS of the noise that we should generate.
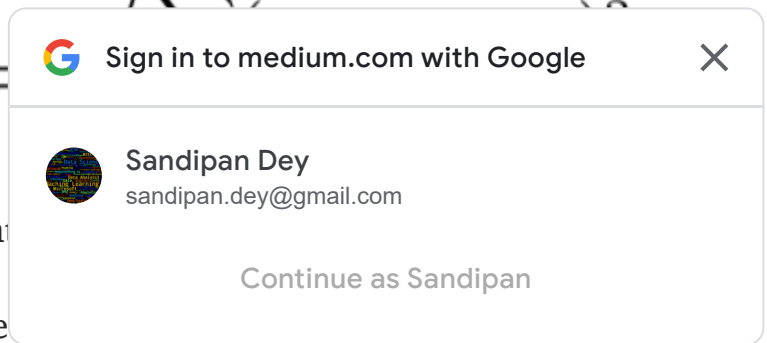
Also,

$$RMS_{noise} = \sqrt{\frac{\sum n_i^2}{n}}$$

$$STD_{noise} =$$

Here STD_noise is the standard devia
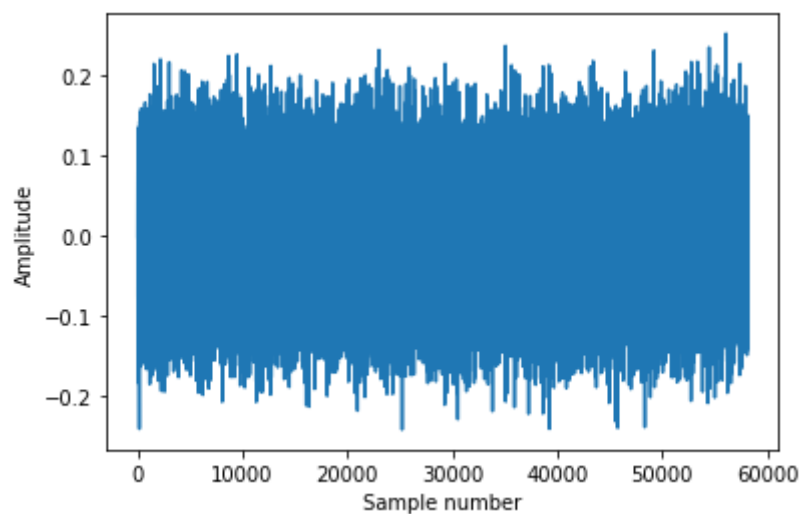
Since mean value of AWGN is zero we

$$STD_{noise} = RMS_{noise}$$

To generate noise, we can sample from a Gaussian distribution with mean =0 and standard deviation = RMS_required

```
noise=np.random.normal(0, STD_n, signal.shape[0])
```
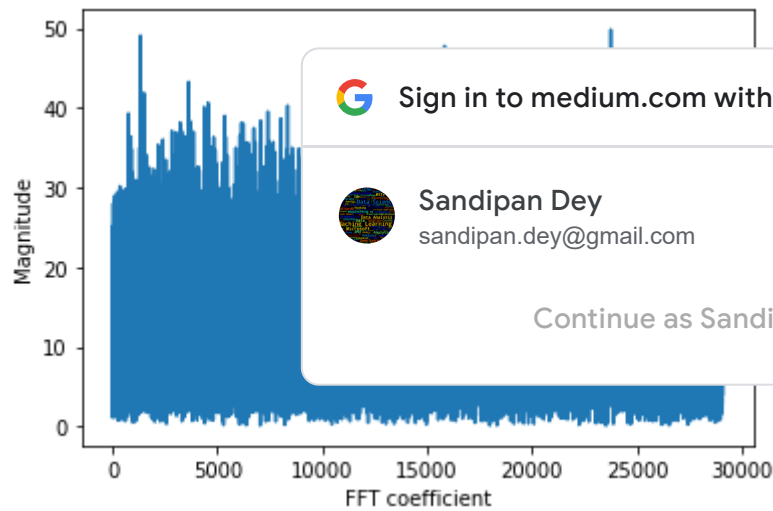
If we plot the AWGN we generated,

Noise plot

Frequency analysis of AWGN

To analyze the frequency content we use fast Fourier transformation (refer the code)

```
X=np.fft.rfft(noise)

radius,angle=to_polar(X)
```
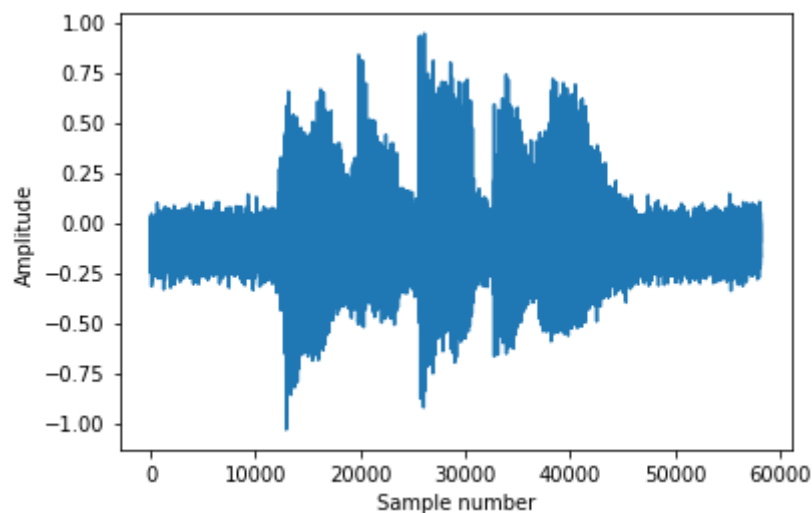
Frequency distribution of noise

We can see that AWGN we generated has somewhat equal frequency distribution. This satisfies the "white" condition for AWGN.

Finally we can add the noise to signal by

```
signal_noise = signal+noise
```

where *signal_noise* is the noise-added signal

Noise-added signal (SNR=10)

Mixing with real world noises

Here we do not generate any data. Instead we use another audio clip which contains noise. What exactly we mean by noise depends on the particular application.

To do this, we need to calculate the RMS value of the signal and the provided noise. Then we modify the noise (multiply e[...] resulting noise would have the require[...]

As in the case of AWGN, we can obtai[...] "change" our noise audio clip so that i[...]

What happens if we multiply the whole signal (element-wise) by a constant (say "a")? Its RMS value gets multiplied by "a" too according to the equation below.

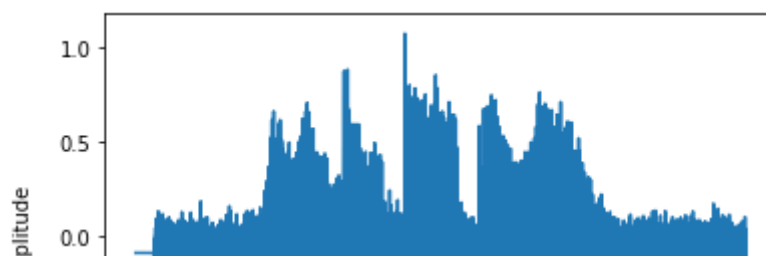$$\sqrt{\frac{\sum (a*n_i)^2}{n}} = a * RMS_{noise} = RMS_{required}$$
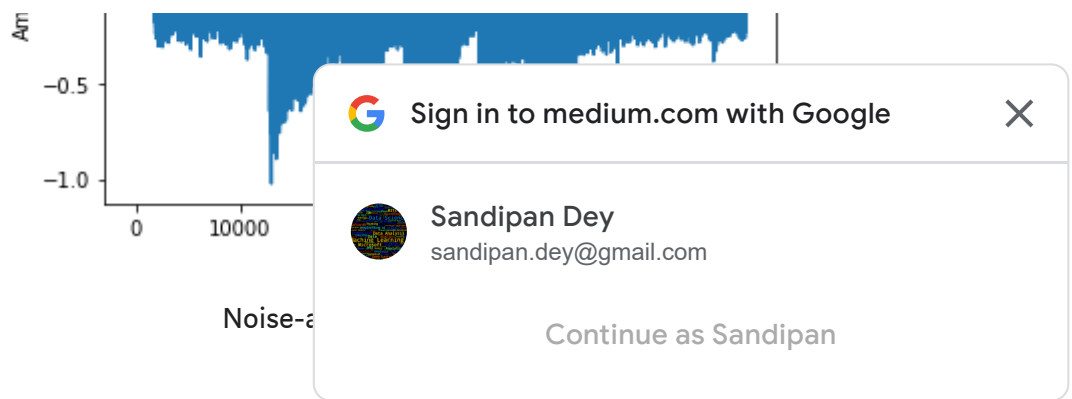
Change the RMS value of a signal

We can calculate the RMS_noise using the noise clip provided. Then we can find the constant "a" using the equation above. After that we can modify the noise by multiplying it with "a" element-wise.

The noise audio clip I used (water running from a faucet):
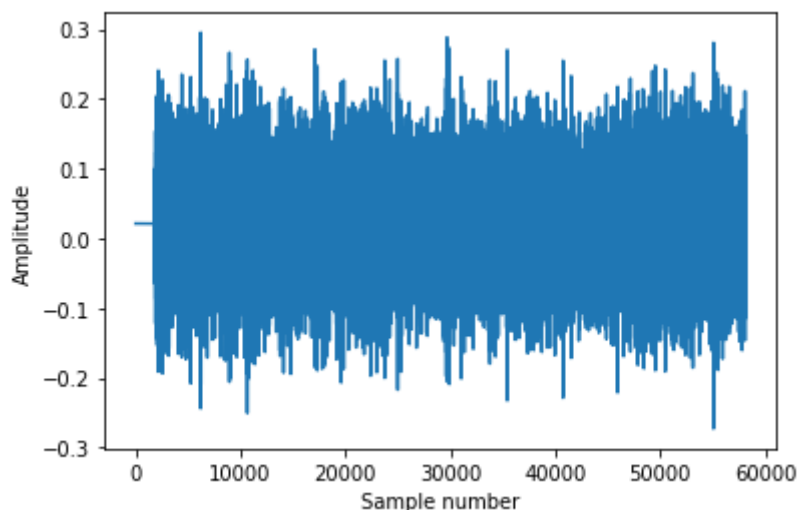
Noise of running water

Noise-a

To listen to the signal and noise I used and also to the noise-added audio files that were created by adding noise to the signal, go to

Adding noise to audio data

Some times we need to add noise to audio data. One examples is when we ealuate machine learning models which classify...

sleekeagle.github.io

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