Exercises for
Introduction to Machine Learning
Paul Stoewer, Johannes Enk, Xingjian Kang, Yu Gao, Oliver Korn
Task 1: deadline: 18. May 2022

Pattern Recognition Lab

Exercise 01: Sampling

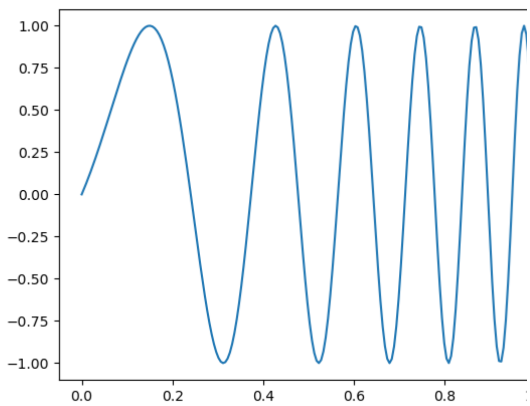
Exercise 1 Sampling Theorem

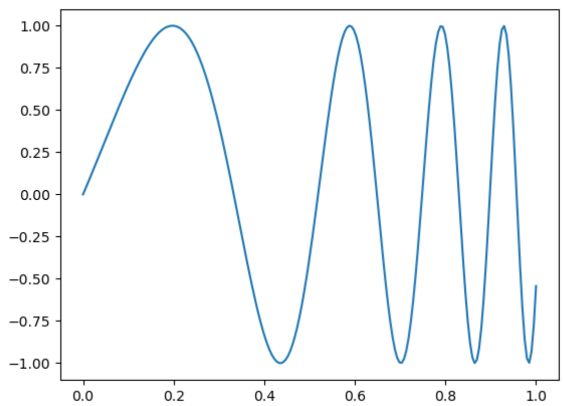
(a) Create a module *chirp.py*. In this module, create a function

$$createChirpSignal(samplingrate, duration, freqfrom, freqto, linear)$$

where a chirp-signal is generated and returned. The user should be able choose between a linear and an exponential chirp-signal through setting the variable $linear$ to $True$ or $False$. The sampling rate ($samplingrate$), the $duration$ in seconds and the starting ($freqfrom$) and end frequency ($freqto$) has to be defined. It is not allowed to use the provided function *scipy.signal.chirp*, but of course you can check your result by comparing it to the signal.

(b) In the existing module *main.py* (from Task 1): Create a linear and an exponential chirp signal by calling your chirp function. For example: $samplingrate = 200$, $duration = 1$, frequency from 1 to 10 Hz.





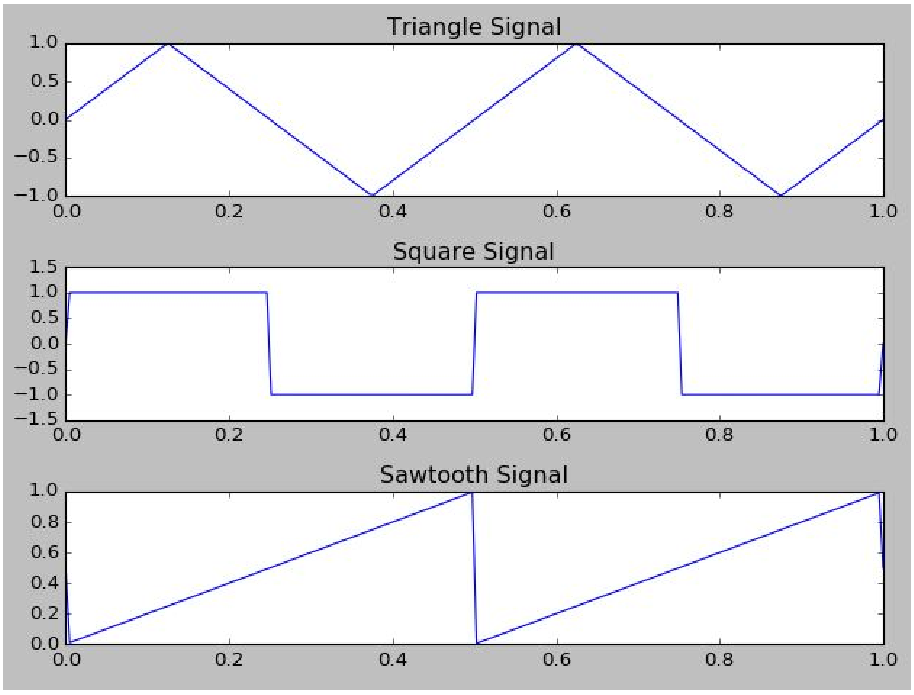
Exercise 2 Fourier Decomposition

In this task, we want to reconstruct a Square, a Triangle and a Sawtooth Signal by implementing their specific Fourier Decomposition functions according to the lecture slides (Chapter 3).

(a) Create a module *decomposition.py* and define the three functions shown below returning the specific signal function over the time of one second. $samples$ denotes the number of samples, $frequency$ the signals frequency, $kMax$ the last computed k and $amplitude$ the amplitude for the sawtooth signal.

- $createTriangleSignal(samples, frequency, kMax)$
- $createSquareSignal(samples, frequency, kMax)$
- $createSawtoothSignal(samples, frequency, kMax, amplitude)$

(b) Test your function in the existing module *main.py*. (Example: $samples = 200$, $frequency = 2$, $kMax = 10000$, $[amplitude = 1]$)



Exercise 3 **Tuning a Piano**

Bob, your best friend, has had his piano tuned by Alice. You know that Alice often goes to loud concerts, so it is likely that her hearing is damaged. Thus, you believe she did not tune the piano properly. Moreover, you righteously dislike her since the day she said that dogs are better than cats... You would totally love to show Bob what a sloppy job she did!

(a) Bob recorded some notes played with his piano, and uploaded them on StudOn. He kindly converted them to Numpy arrays. Bob said these notes are A2, A3, A4, A5, A6, A7, and another one but he forgot which one. The sampling frequency is 44100Hz. Download these files from StudOn.

(b) Complete the `load_sample` function. Use the `load` function of Numpy to load the sound files. I recommend to plot one of them using `matplotlib` to see what it corresponds to. This function should return a short part of the signal shortly after its loudest peak (i.e., when the hammer hits the string). To do so:

- Find the position of the highest absolute value of the signal (hint: use `np.argmax`),
- Add `offset` to this position, as start of the signal,
- Keep only the N=`duration` following values.

(c) Complete the `compute_frequency` function. It must return the main frequency present in the input sound. To do so, the following steps are needed:

- Compute the magnitude of the Fourier transform of the sample. Use an external library to calculate the Fourier transform,
- Find the highest peak corresponding to a frequency higher than `min_freq`, and return the frequency corresponding to this peak.

(d) Using the function that you completed, compute the frequencies of all notes that Bob sent you, and compare them to the expected values[1]. Also, find out what the mysterious note is.

(e) During the oral submission, after having presented your solution, give your opinion on Alice' hearing damages, and tell the tutor how wrong she is about cats.

Comments:
Please upload the code of your solution to StudOn once it passes the tests from ***`test_signals.py`*** *and* ***`test_piano.py`***. *There is no need to upload the plot(s) that you made.*

[1]`https://en.wikipedia.org/wiki/Piano_key_frequencies`