Lecture "Digital Signal Processing"

Prof. Dr. D. Klakow, summer term 2019

Tutorial 7

Submission deadline: 03.06.2019, 10:15

Submission Instructions:
You have one week to solve the tutorials.
The code should be well structured and documented. Do not use any Matlab-Toolbox or Python external libraries if not mentioned that you could use it.

- You are allowed to hand in your solutions in groups of two students.
- The theoretical part should be submitted before the lecture.
- For the practical tasks please submit files via the email address
  Tutorial 1: dsp.tutorial1@gmail.com Tutorial 2: dsp.tutorial2@gmail.com
- The subject of the letter should be [**DSP TUTORIAL X**]. **X** is the tutorial/assignment number.
- Rename and pack the main directory:
  Ex05_matriculationnumber1_matriculationnumber2.zip.

The directory that you pack and submit should contain the following files:

- code files and supporting files (library, image and sound etc.);
- file "answers.pdf" which contains answers to the questions appearing in the exercise sheet;
- file "README" that contains an information on all team members:
  name
  matriculation number
  email address.
- Note: If you use Jupyter Notebook, you don't have to submit "answers.pdf".You can write your theoretical answer in the markdown area

1 Spectral Subtraction

The spectral subtraction method is a simple and effective method of noise reduction. It is assumed that the signal is distorted by a wide-band, stationary, additive noise. The noisy signal is $y[m]$, the noiseless signal is $x[m]$ and the noise is $n[m]$.

$$y[m] = x[m] + n[m]$$

In the frequency domain(Fourier Transform), this may be denoted as:

$$Y[jw] = X[jw] + N[jw]$$

or

$$X[jw] = Y[jw] - N[jw] - - - - - - - - -(1)$$

1.1 (2P) Subtask

We don't know about $N[jw]$. So we have to approximate it from many recorded instances of noise. Given 5 instances of noise in .wav files. Write a program that approximate the noise spectrum $\hat{N}[jw]$using following formulas. Plot the approximated noise.

$$\hat{N}[jw] = \frac{1}{K} \sum_{k=0}^{K-1} |\tilde{N}_k[jw]| - - - - - - -(2)$$

and

$$|\tilde{N}_k^i[jw]| = 0.8 \times |\tilde{N}_k^{i-1}[jw]| + 0.2 \times N_k^i[jw] - - - - - (3)$$

Note: Equation 2 is just the average of all filtered noise instance. Equation 3 is nothing but first order filtered version of each of the noise instance.

1.2 (2 P) Subtask

Given a noisy signal "noisy-signal.wav". Using equation 1 find the spectrum of noiseless signal. Plot the noiseless signal in the frequency domain and time domain.

2 Wiener Filter

2.1 (1.5 P)De-convolution

Wiener filter can be used in image de-bluring. Prove it mathematically?

2.2 (1.5 P) Multiplicative Noise

Wiener filter works for additive noisy channel. We can also model Wiener filter for multiplicative noisy channel, however this formulation would not be correct. Prove that mathematically.

2.3 (2P) Wiener Filter in Practise

Write a function which takes as input a stationary, zero-mean process $x[k]$, another stationary, zero-mean target process $y[k]$, and an odd filter length $M = 2N+1$ and generates the Wiener IIR Filter $h[k]$ so that $\hat{y} = x * h$ optimally approximates y.