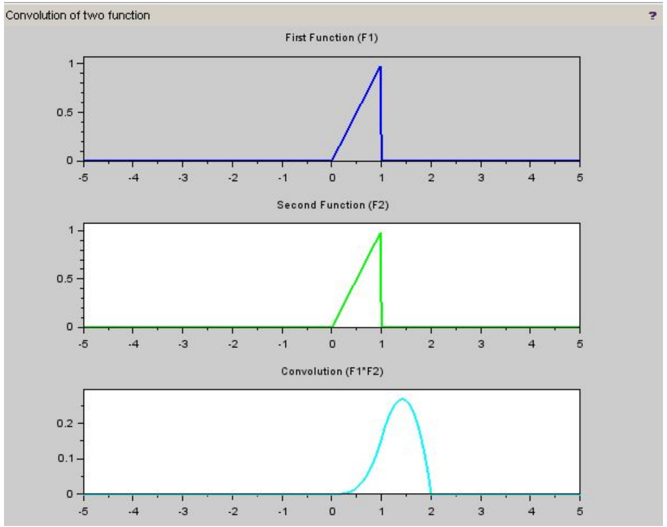
Linear Systems and Signals
Convolution

Aidar Ahmetshin
Evgenii Maksimychev
Yuriy Sukhorukov

Task 1: Impulse response and convolution

- Record Impulse Response Characteristics of some building
- Implement convolution algorithm
- Perform convolution of recorded IRC and given track
- Compare our convolution implementation with Scilab conv method



Convolution implementation

- Fourier transform of signals convolution is equal to multiplication of Fourier transforms of these signals:

$$FT(x * y) = FT(x)\,FT(y)$$

- So to perform signals convolution we can take Inverse Fourier Transform of multiplication of Fourier transform of signals

$$x * y = IFT(FT(x)\,FT(y))$$

Result of convolution

- Matched Filter
  - Linear system distorting input waveform
  - Used to search for signals of a known shape against a background of noise
  - Confirm signal on air
  - Check arrival time

Comparison of our and Scilab convolution

- Left plot - result of convolution method from Scilab
- Right plot - result of our convolution
- Visually plot looks quite similar
- Scilab implementation works 2 times faster (our - 0.6 sec, Scilab - 0.3)

Task 2: Frequency Filtering with IIR Filters

- Implement Infinite Impulse Response Filter
- Set IIR to low-pass filter
- Set IIR to high-pass filter
- Apply filters to a given recording, analyse the result

Infinite Impulse Response Filter

- Infinite Impulse Response Filter is a combination of two linear transforms over an input signals:

$$y[k] = \sum_{m=0}^{M} b_m \cdot x_{k-m} + \sum_{n=1}^{N} a_n \cdot y_{k-n}$$

where x - input signal
y - previous element of system

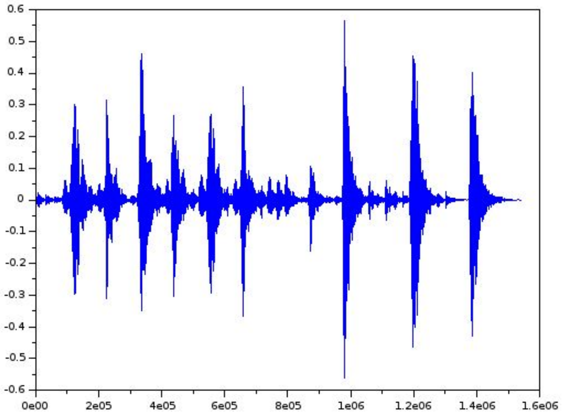
- By tuning coefficients a and b it is possible to construct different kinds of filters

Low-pass and High-pass filters

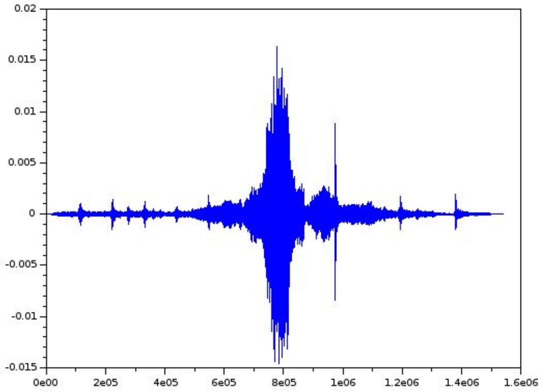
- High-pass and Low-pass filters are widely used particular cases of IIR filter
- Low-pass filter removes parts with low frequencies from our signal
- Low-pass filter removes parts with high frequencies from our signal

Applying filters to music recording

- Low-pass filter make the violin sounds more quiet and smooth
- After applying low-pass filter bass become leading instrument
- High-pass filter dumps the bass sounds
- Violin becomes leading instrument after applying high-pass filter



Low-pass result



High-pass result

Extra Goal

- Shallow (Lady Gaga, Bradley Cooper) by “The Kotiki” band
  - Alexander Gruk: voice, guitar
  - Daria Miklashevskaya: voice, piano
  - Susana Gimaeva: violin
  - Yuriy Sukhorukov: drumz
- Recorded in the Music Studio
  - Sports Center