Digital Signal Processing - DSP
(PDS - Processamento digiral de Sinais)
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Spectral analysis

Non stationary signals are characterized by changing its characteristics throughout time. The Fourier transforms in these cases must be localized in time, that is, instead of computing the Fourier transform of the whole signal, several Fourier transforms are computed over smaller segments where the signal may be considered approximately stationary. The analysis based on these strategies, are usually denominated *time-frequency* analysis.

In this work the *Short Time Frequency transform* is used, where the whole signal is analyzed by pieces. The Fourier Transform Magnitude of each segment is represented in a line of an image called *spectrogram*. In this way, it is possible to observe the spectral contents evolution along the time. From a mathematical point of view the STFT is obtained by multiplying the whole signal by a N dimensional sliding window, $w(n)$. The most obvious choice is the rectangular window,

$$w_N(n) = \begin{cases} 1, & 0 \le n \le N-1; \\ 0, & \text{otherwise.} \end{cases} \tag{1}$$

The *Discrete Fourier transform* (DFT) of each segment is computed according to the following equation

$$X(k,r) = \sum_{n=0}^{N} w(n)x(n+r)e^{-j\frac{2\pi}{N}kn} \tag{2}$$

where each analyzed segment $x(n)$ is in the interval $[r, r+N-1]$.

In this work a telephonic dial system by tones is used, called *Dual Tone Multi-Frequency* (DTMF). In this system each phone key produces a sound which is the sum of two sine waves with frequency f_a and f_b, defined in table below. The sampling frequency of the audio file is 8000 Hz.

Experimental section

1. Write a function $dtmfdial()$ that receives the phone number and produces an audio vector with the corresponding DTMF sequence. The multi-frequency signals and the silence intervals between digits must be at least 40 ms.

2. Download the audio file 'touchtone.wav' with the dial register of an unknown number. Implement a routine to automatically detect the underlying number. Use the spectrogram function to detect the number.

   Code example:
   $x =$audio data;
   $[B, F, T] = spectrogram(x, 300, 150, [], 8000);$

$f_a(Hz) \setminus f_b(Hz)$	1209	1336	1477
697	1	2	3
770	4	5	6
852	7	8	9
941	$*$	0	$\sharp$

$B = abs(B);$

%Spectrogram binarization
$Y = 1.0 * (B > max(max(B)) * 0.9);$
$mesh(T, F, Y);$

3. Try several window dimensions in order to improve the digit detection process.

4. Change the routine implemented in item 1) introducing a random component at the coding frequencies and test the robustness of the detection algorithm using a phone number generated by you.

5. Generate a phone number and try to establish a phone communication by approximating the phone microphone to the PC headphone