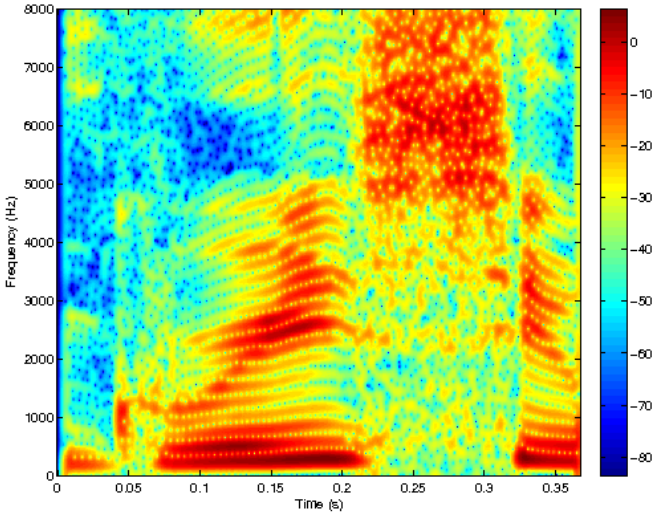
High-resolution time-frequency analysis as a tool to locate non-stationary moving acoustic sources in the automotive industry

Time-frequency analysis makes it possible to visually assess the frequency content variation of a signal over time. This visualization is made in forms of spectrograms, also called waterfall diagrams. Time-frequency analysis presents the dilemma of providing either a good time or frequency resolution, but not both, and this is a problem when analyzing sound measurements of accelerating passing-by vehicles.



When an accelerating vehicle is moving towards and then away from a measuring microphone, it is of great interest to perform a high-resolution time-frequency analysis of the sound signal to track the frequency variation of various sources. If the analysis can be done well enough, it should be possible to separate two sources having tonal frequencies very close to each other. Another goal in this specific measurement case is to use the Doppler effect induced by the movement of the vehicle to locate sources. In fact, the sudden change of frequency at the instant a source is passing by a measurement microphone, can unveil its location.

A successful high-resolution time-frequency analysis must take into account the Nyquist principle for the sampling of digital signals, the adverse effect of windowing time signals with for instance Hann or Hamming windows and a way to tackle it. Other aspects like zero-padding, shortest time window for short-time Fourier transform, and the time delay for a sound to reach the microphone need to be considered.

In this Master's Thesis, we wish to address the challenges described above. The theoretical study will be complemented by an application to real sound measurement of an accelerating vehicle measured during roughly 4 seconds over a distance of [-20;20] meters where a measuring microphone is located at position x=0 meters.

Keywords: High-resolution time-frequency analysis, zero-padding, windowing, frequency domain deconvolution, automotive, Doppler effect, frequency tracking, re-assigned spectrum.

Required knowledge: Fourier analysis, Matlab or Python.

References:

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