From Fourier Series to Analysis of Non-stationary Signals – IX

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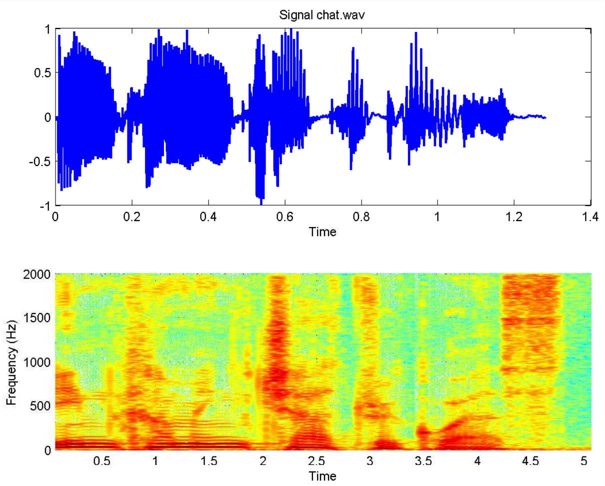
Non-stationary and Stationary Signals

Comments to project on speech analysis



click to play

Comments to project on speech analysis

- Speech is non-stationary signal where properties change quite rapidly over time.
- For most phonemes the properties of the speech remainS invariant for a short period of time ($\approx$ 5–100 ms).
- These segments are assumed to be stationary and we can use DFT for any $\approx$ 5–100 ms segment.

Comments to project on speech analysis

- Most of speech processing is done by taking short overlapping windows and processing them.
- Windowing: a long signal is multiplied with a window function of finite length, giving finite length weighted version of the original signal.

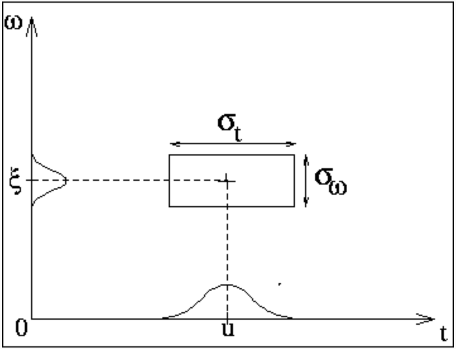
Comments to project on speech analysis

- In speech processing the shape of the window function is not that crucial.
- Usually some soft window like *Hanning*, or *Hamming* are used. Their sideband lobes as substantially smaller than in a rectangular window.
- In speech recognition the windows are usually overlapping 10 ms each other.

Principle of uncertainty

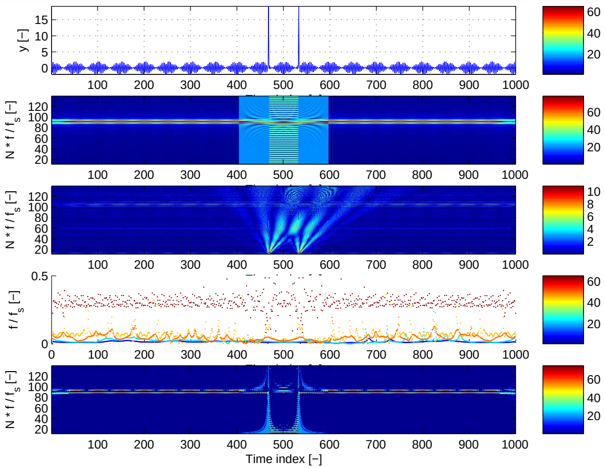
- If $f(t)$ is non-zero with a compact support, then its Fourier transform cannot be zero on a whole interval.
- If its Fourier transform $F(\jmath\omega)$ is compactly supported, then it cannot be zero on a time interval.
- Hence, even if the Heisenberg constraints are verified, it is impossible to have an function in space $\mathbb{L}^2$ which is compactly supported both in the time and frequency domains.

Principle of uncertainty



- In particular, there is no instantaneous frequency analysis for finite energy signals.

Discrete Zolotarev Transform

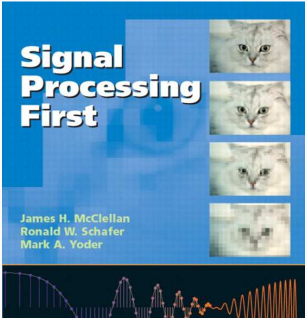


Harmonic signal with two pulses, STFT, WT, HHT and DZT spectrogram

MATLAB project

MATLAB project with music scale

```
% J. H. McClellan, R. W. Schafer, and M. A. Yoder
% Signal Processing First, ISBN 0-13-065562-7.
% Prentice Hall (c) 2003
% spectrogram of a music scale
% M. Vlcek, Prague, 2010
```



MATLAB project with music scale

```
% make a scale for C major
c1=40; cis=41; d=42; dis=43; e=44; f=45;
fis=46; g=47; gis=48; a=49; b=50; h=51 c2=52;
keys = [ c1 d e f g a h c2 ];
% Remember: key #49 is a1 (i.e. 440 Hz)
```

tone	C	D	E	F	G	A	H	C
f Hz	262	294	330	349	392	440	494	523

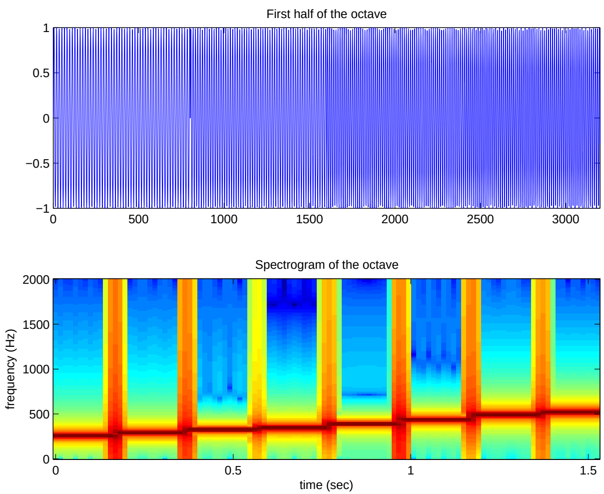
MATLAB project with music scale

```
Fs = 4000;
t0 = 0.2;
tt = 0:(1/Fs):t0;
y2 = [];
for k = 1:length(keys)
  keynum = keys(k);
  % add 12 to move up 1 octave
  freq(k) = 440 * (2 .^((keynum - 49)/12));
  % based on A=440 Hz
  y2 = [ y2, cos( 2*pi*freq(k)*tt - pi/2 ) ];
end
% play it
sound(y2, Fs);
```

MATLAB project with music scale

```
figure(1);
Fmax = Fs/4;
Nfft = 256;
Nover = 200;
% uses an old version of 'specgram'
[B,F,T] = specgram(y2, Nfft, Fmax, [], Nover);
imagesc(T, F, db(B, 40));
title('Spectrogram of the octave');
axis('xy');
colormap('default');
ylabel('Frequency [Hz]');
xlabel('Time [sec]');
```

MATLAB project with music scale



MATLAB project with music scale

1. Replace the old command in MATLAB `specgram` with `spectrogram`.
2. Before applying this, carefully read the help for `spectrogram`!
3. Save your sound using `audiowrite('CDscale',y2, Fs)`.

   click to play

4. It sounds rather artificially, can you find the way of improving the record?
5. Select a scale, and compose a Christmas carol with an improved scale. Deliver the code that generates the wav format by December 11, 2017.

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