ECEN313 Signals and Systems Projects

Project team must consist of 3 to 5 students. At the end of the project each group delivers:

- (5 points) A PDF report, describing the project elements and how it was implemented using MATLAB (you may use other programming languages if you like) with snapshots of the graphical user interface and the codes included as an appendix to the report. Used codes need to be submitted on Moodle as well.
- (5 points) A 10 minutes presentation (2 minutes each student) describing your work and demonstrating output results in the project, each student must show his rule and the part he/she contributed to.
- A bonus of 2 points will be given when writing your report in LaTeX/LyX [1], [2].

Three projects are proposed, from which each group can pick one to do. However other project ideas with similar theme can be adopted after consulting your course instructor.

1 Voice Spectrum Analyzer

The objective of this project is to build an interactive Octave code (you may use other programming languages if you like) that captures user voice for a certain time, and display the voice signal both in time and frequency domain demonstrating its spectral content.

Graphical User Interface

You need to build a user interface [3] where the user gives the following inputs:

- Maximum time of captured voice signal in seconds $T_{\max}$.
- Sampling frequency in Hz.

Output

After capturing T_{max} or clicking the stop button the system displays two windows:

- One that displays the voice signal as function of time. User must be able to change the time axis scale, and the vertical sacle as well.
- Another window showing the amplitude/phase of the spectrum of the voice spectrum. User must be able to control the display spectrum (Amplitude, phase, and energy) versus frequency, beside the ability to control the horizontal frequency axis and the vertical axis.

2 Filtering of Electrocardiogram (ECG or EKG)

Electrocardiogram (ECG or EKG) is the signal captured using non-invasive electrodes. The signal gives indications about the medical heart health of the person to whom it was recorded. A number of ECG signals was collected in a master thesis study [4] and the corresponding data set is made accessible to everyone through [5].

Usually such weak signal is interfered with the 50/60 Hz main supply signal. In this project you are going to work on the ECG dataset [5], to plot the signal and its spectrum. In order to read the corresponding signal files you may need some reader file corresponding to plateform you are going to use, i.e. MATLAB/Octave reader, or PYTHON reader [6].

Graphical User Interface

You build a simple interface using MATLAB/Octave [3] (you may use other programming languages if you like) with capability to choose one of the ECG waveforms from the dataset [6].

Output

- User defines the horizontal and vertical limits of the horizontal and vertical axes.
- A plot window shows the amplitude/phase of the spectrum of the ECG signal.

3 Window Fourier Transform

Fourier transform gives the overall frequency spectrum as an accumulative transform of the signal over its entire time. One method to describe the frequency variation of the signal behavior with time is to use what is known as window Fourier transform. So instead of using $\phi_\omega(u) = e^{j\omega u}$ for Fourier transform, a "window" complex exponential function $\phi_{\omega,t}(u) = g(u-t)e^{j\omega u}$, where $g(u)$ is a window function with some window function centered at the origin with some effective width σ_t, making the shifted version $g(u-t)$ centered at t. The spectrum of $\phi_{\omega,t}(u)$ will be centered around ω with effective width of σ_ω. The effective widths σ_t and σ_ω, satisfy the "quantum" uncertainty,

$$\sigma_t \cdot \sigma_\omega \geq \frac{1}{2} \tag{1}$$

The regular Fourier transform corresponds to $g(u) = 1$ with $\sigma_t = \infty$ and $\sigma_\omega = 0$

The window Fourier transform WFT $Sx(t, \omega)$ is defined as,

$$Sx(t, \omega) = \int_{-\infty}^{\infty} x(u)\phi^*_{\omega,t}(u)du = \int_{-\infty}^{\infty} x(u)g(u-t)e^{-j\omega u}du$$

The window Fourier Transform is now a function of time t and frequency ω compared to the regular Fourier transform $\hat{x}(\omega)$ which is solely function of frequency. A two dimensional color map plot is usually used to visualize window Fourier transform $Sx(t, \omega)$.

Output

- Plot the two dimensional WFT color map for the chirp sinusoidal,

$$x(t) = \sin\left(\pi t^2\right) \tag{2}$$

  with instantaneous radian frequency $\omega_{\text{inst}} = 2\pi t$ increasing linearly with time t. Use the following window function,

$$g(u) = \sqrt{\frac{2}{3}} \begin{cases} 1 + \cos(\pi u) & -1 \le u \le 1 \\ 0 & \text{otherwise} \end{cases}$$

- Propose a Gaussian window signal $g(u)$ that satisfy the equality of uncertainty relation (1), and plot the corresponding two dimensional color plot of WTF of the chirp pulse (2).
- Apply a Gaussian window to visualize the WFT two dimensional color plot of a captured voice signal.

References

[1] *LaTeX - A document preparation system.* Accessed: Apr. 7, 2024. [Online]. Available: `https://www.latex-project.org/`.

[2] *LyX | LyX – The Document Processor.* Accessed: Apr. 7, 2024. [Online]. Available: `https://www.lyx.org/`.

[3] *MATLAB GUI*, en. Accessed: Dec. 2, 2023. [Online]. Available: `https://www.mathworks.com/discovery/matlab-gui.html`.

[4] L. T.S., "Biometric human identification based on electrocardiogram," Ph.D. dissertation, Faculty of Computing Technologies and Informatics, Electrotechnical University "LETI", Saint-Petersburg, Russian Federation, Jun. 2005. [Online]. Available: `https://www.physionet.org/physiobank/database/ecgiddb/biometric.shtml`.

[5] T. Lugovaya, *The ECG-ID Database*, 2011. DOI: `10.13026/C2J01F`. [Online]. Available: `https://physionet.org/content/ecgiddb/`.

[6] *Waveform Database*, en-US. [Online]. Available: `https://wfdb.io/`.