MASTER INSTRUCTIONS

A. Overview:

Leo Towle 's lab - University of Chicago

Contributors: Dominic Dicario, Tuan Pham

Purpose: Designing a GUI to visualize streamed EEG data and indication of seizure activity based on customized threshold via root-mean-square and spectral-related calculation of the EEG data

Requirements: Communication with EEG data port. The way this was set up assumes communication with softwares like ***OpenViBE Designer*** and ***OpenViBE Acquisition***

Summary Description:

This program reads in data from a TCP server generated by ***OpenViBE Designer***. For the acquisition, it takes in the data given at 512 Hz signal delivered in 4-sample chunks. The root-mean-square (RMS) of a certain length of data is calculated like a sliding RMS function. The short-time Fourier Transform (STFT) of a certain length of data is also obtained to calculate the spectral of the signal, as well as the total band power of a certain frequency band (limited band power or LBP).

The program also evaluates the alarm level of both RMS and LBP. If the RMS (or LBP) approaches certain upper or lower bounds, the graphical interface of the program will change the color of a bar to signify this, the default choice is from green (normal) to yellow/gold (warning), to red (danger). Right now, the upper and lower bounds of these ranges has been arbitrarily decided. To use this program for the visual prosthesis, these values will either have to be pre-determined or determined after experimentation has begun. We must decide whether to err on the side of safety or risk.

B. General documentation and related files:

OpenViBE Acquisition Server (sometimes referred as *OVAcq*)	The server to collect data from ***V-Amplifier***
OpenViBE Designer (sometimes referred as *OVDes*)	The software to create communication between the program and the ***OpenViBE Acquisition Server***, as well as additional preprocessing and channel selector
docs//diagram.pdf	The general diagram of the program and communication with ***OpenViBE*** software
docs//diagram.pptx	Go through the animation to see the flow of the diagram
docs//calculation_notes.pdf	Explanation of • sliding RMS calculations (see "*RMSCalculator.cs*" for implementation), • spectral-related calculations (see "*STFTCalculator.cs*" for implementation) • instantaneous alarm level evaluation (see "*MainForm.cs*" particularly `MainForm.ReturnAlarmLevelAndColor`).
docs//ovdes_acq_scenario.png *ovdes_scenarios//acq_setup.mxs*	***OpenViBE Designer*** scenario for communication with ***OpenViBE Acquisition Server***
docs// ovdes_sine_sim_scenario.png *ovdes_scenarios// sine_sim_setup.mxs*	***OpenViBE Designer*** scenario for sinusoidal simulator, mainly for testing the GUI
docs//prompt_demo.png	Example demo of the configuration dialog (`Prompt.ConfigPrompt`) and main parameter input modification dialog (`Prompt.MainPrompt`)
docs//gui_demo.png	Example demo of the GUI (`MainForm`)
docs//gui_components.png	The component names in `MainForm` as in "*MainForm.cs*" Please also refer to "*MainForm.Designer.cs"*

MainForm.cs	The main GUI to stream the data and the alarm. Will generally be displaying: • Occipital EEG data • Their difference • Root mean square (RMS) • Short-time Fourier transform (STFT) • Limited band power (LBP) • Flashing alarm for every calculation of RMS for each channel • Flashing alarm for every calculation of LBP for each channel • Alarm rates (for a certain period of time, sum of all channels) for 3 alarm levels of RMS • Alarm rates (for a certain period of time, sum of all channels) for 3 alarm levels of LBP
MainForm.Designer.cs	Layout of the components in `MainForm`
Promp.cs	Containing the 2 dialog prompting for configuration file loading options (`Prompt.ConfigPrompt`) and for modification of the parameter configuration to run `MainForm` (for example, the connection parameters, calculation parameters and alarm thresholds, …) (`Prompt.MainPrompt`)
ApplicationInputParameters.cs	Contains the configuration parameters in order to connect `MainForm` with ***OpenViBE Designer***, as well as calculation parameters, display parameters, and alarm thresholds (refer to this file for explanation of all the detailed options)
_config_file.txt *demo_config_file.txt* *customized_config_file.txt*	These are all configuration files. *"_config_file.txt"* is the default configuration file. The other 2 are just other examples. *"demo_config_file.txt"* was used to run the demo in the demo files in *"docs"*
RMSCalculator.cs	Root mean squared (RMS) calculator of streaming data and tally of alarm levels. Particularly the RMS calculation is done like a "sliding window" calculation, not of the entire data (because this is streaming data). Also keeps tally of alarm levels of RMS values. Please also refer to "*docs//calculation_notes.pdf"*
STFTCalculator.cs	Short-time Fourier transform (STFT) and periodically keep tally of spectral alarm levels. Particularly, calculate both the STFT, then the total power of a certain frequency (limited-band power or LBP). The alarm is from the LBP alarm levels. Please also refer to "*docs//calculation_notes.pdf"*
Additional required NuGet packages for the program:	• For *plotting*: `LiveCharts, LiveCharts.Geared, LiveCharts.WinForms, LiveCharts.Wpf` • For *FFT calculation*: `Accord, Accord.Math`

C. Instructions:

An example of connection and setup with the ***OpenViBE*** software is shown below. Note: you can also refer to the powerpoint file in "*docs//diagram.pptx*" and go through the animation to see the layout of the program and connection with ***OpenViBE*** software.

1. Connect the ***V-Amplifier*** to the computer and install any drivers you may be prompted to. The *Brain Products* usb will also install some drivers to your PC; these are needed for the *V-Amp* (supposedly)

2. Open ***OpenViBE Acquisition Server***. Select *V-Amp/Fast Amp* from the *Driver* drop down menu. Adjust "`Drift tolerance = 2.00 ms`" or lower from the *Preferences* button.

Set "`Sample count per sent block = 4`".

3. Open ***OpenViBE Designer*** and the desired scenarios. There are examples of such set up in the folder "*ovdes_scenarios*". The sine simulation set up (no acquisition) for testing purposes is "*sine_sim_setup.mxs* (see "*docs//ovdes_sine_sim_scenario.png"*). The acquisition set up example is "*acq_setup.mxs*" (see "*docs//ovdes_acq_scenario.png"*).
   Notes:
   a) Assure the "`Matrix Sender[TCP port] = 1234`". This number is arbitrary, as it just needs to match up with the port number in the configuration file or in the field with the same name in `MainPrompt`.
   b) Assure the "`Acquisition client`" box has the same acquisition server port as the number on ***OpenViBE Acquisition Server*** "`Connection port`". (This does not apply for sine simulator)
   c) You can modify and save new settings in ***OpenViBE Designer*** as a scenario file as well.

4. Hit Start at the top of ***Visual Studio***, or run this program in the packaged way you have decided. Then, hit the play arrow on top of ***OpenViBE Designer***. Or you can do it the other way around as well. Once the program is running, the first dialog will appear is the `ConfigPrompt` (see "*docs//prompt_demo.png"*). There will be 3 options for you to choose from. Please refer to `Prompt.Config_Options` for detailed discussion. Just briefly, you can either
   a) create a new configuration file and edit later in `MainPrompt`, then go to `MainForm` to plot; or
   b) load in an existing configuration file and edit in `MainPrompt` then go to `MainForm` to plot; or
   c) load an existing configuration file and go straight to `MainForm` to plot.

5. Then `MainPrompt` will appear if option (a) or (b) is chosen (see "*docs//prompt_demo.png"*). You can then edit the parameters to configure the application.
   For details of what each of the parameters means, please refer to "ApplicationInputParameters.cs" discussion of object's attributes and `OptionSections`.

6. Then `MainForm` will appear ((see "*docs//gui_demo.png"*).
   a) The GUI's `Log` window will print out either error message if there are connection issues, or print out a welcome message saying that connection is successful, along with the configuration parameters.
   b) Plotting will happen as in "*docs//gui_demo.png*". Please also refer to "*docs//diagram.pdf*" for what they plot out.
   c) You can change the display vertical offset and gain for the EEG plots and RMS plots in the lower left bottom as in "*docs//gui_demo.png*".

D. <u>General future considerations:</u>

- Communication issues between the program and OpenViBE Designer's Matrix Sender technically cause uneven sampling of the streaming data. Although for visualization purposes, the extent of which can be considered acceptable. However, for better accuracy (especially for spectral calculation), there are 2 possible solutions:
  - Consider using a different communication software different from OpenViBE. Per recommendation from Jonathan Drucker (BrainVision LLC, Sales@brainvision.com), Lab Streaming Layer is an option (1).
  - Specifically for spectral calculation, consider implementing Lomb-Scargle periodogram algorithm for uneven sampled data (see (2); for implementation example, refer to (3)).
- Regarding measures for detection of seizure, the ones in this program are linear methods. Nonlinear methods can be considered as well, such as Kolmogorov entropy (see (4) and (5); for implementation example, see (6) appendix).
- For visualization purposes, also consider addition of modifying the Y-axis limits as well.
- For file saving purposes, consider saving the data separate from their analysis Additionally, consider saving the files every 15 or 30 minutes instead of saving the whole session in one file. For example, that would look like this:

```
"patientX_dateY_data_00.csv", "patientX_dateY_rms_and_alarms_00.csv",
"patientX_dateY_spectral_and_alarms_00.csv",
```

```
"patientX_dateY_data_01.csv", "patientX_dateY_rms_and_alarms_01.csv",
"patientX_dateY_spectral_and_alarms_01.csv",

"patientX_dateY_data_02.csv", "patientX_dateY_rms_and_alarms_02.csv",
       "patientX_dateY_spectral_and_alarms_02.csv",

…
```

- Modifications of the RMS/LBP alarm thresholds inside the GUI in order to figure out the best thresholds in the first few runs. Then at the end, save the thresholds to a new configuration file. This can be implemented inside "*MainForm.cs*" and "*ApplicationInputParameters.cs*".
- Change the implementation in "*MainForm.cs*" in order to visualize more than 2 channels and their difference. Please refer to `MainForm.InitializePlotSeries` for discussion about this.

E. References:

1. Lab Streaming Layer Wiki. [Online] https://github.com/sccn/labstreaminglayer/wiki.

2. Drongelen, Wim van. Lomb's Algorithm and Multi-Taper Power Spectrum Estimation. [book auth.] Wim van Drongelen. *Signal Processing for Neuroscientists.* s.l. : Academic Press, 2018.

3. Scipy's implementation of Lomb-Scargle. [Online] https://github.com/scipy/scipy/blob/v1.2.0/scipy/signal/_spectral.pyx.

4. *Seizure anticipation in pediatric epilepsy: use of Kolmogorov entropy.* van Drongelen, W, et al. 2003, Pediatr Neurol.

5. *Maximum-likelihood estimation of the entropy of an attractor.* Schouten, Jaap C., Takens, Floris and Bleek, Cor M. van den. s.l. : Phys. Rev. E , 1994.

6. van Drongelen, Wim, Lee, H.C and Hecox, K.E. Seizure prediction in Epilepsy. [ed.] Bin He. *Neural Engineering.* s.l. : Kluwer Academic/Plenum , 2005.