Assignment 4: Electrical/Bioengineering Case Study – Fear Analysis using GSR data

Available: December 4, 2023
Due: Sunday December 17, 2023 @11:55pm

Programming aspects to get familiarized with:
- MATLAB Input/Output
- MATLAB functions
- MATLAB Plotting

Many of the parts of this problem can be done in many different ways. Make sure to explore the documentation of MATLAB to develop your solution.

Background

The human body's sweating is regulated by the autonomic nervous system. In particular, if the sympathetic branch of the autonomic nervous system is highly aroused, then sweat gland activity also increases, which in turn raises the skin conductance, and vice versa. The galvanic skin response (also called electrodermal response, skin conductance, or psychogalvanic reflex) is the measure of the conductance caused by the variation of the human body sweating.

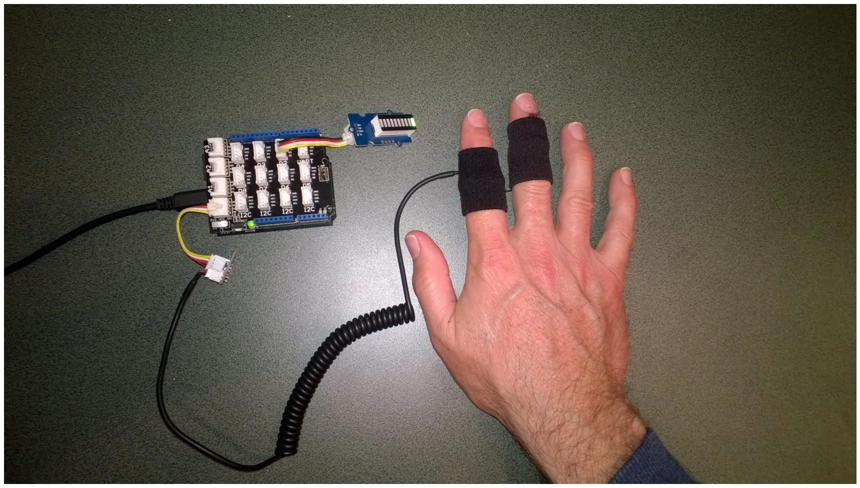
A GSR sensor allows us to measure sweat gland activity, which is related to emotional arousal. So, to measure GSR, we take advantage of the electrical properties of the skin. Specifically, how the skin resistance changes with sweat gland activity, i.e., the greater sweat gland activity, the more perspiration, and thus, less skin resistance. GSR activity is typically measured in "micro-Siemens (uS)" or "micro-Mho (uM)", mirroring the conductance of a certain material.

GSR is not only used to monitor your emotional arousal. In psychology, the data from the GSR sensor can be analyze to determine whether a person is lying or not. In fact, the GSR sensor has been widely used in our lives, especially in some medical facilities, psychology, polygraphs, etc.

In this assignment, you will explore processing GSR data to detect the presence of fear using MATLAB.

Data Acquisition System

The Grove GSR sensor (https://wiki.seeedstudio.com/Grove-GSR_Sensor/) is utilized to record the GSR data provided in this assignment. The sensor uses two electrodes that are attached to the second and third fingers on one hand. The output of the sensor, an analog voltage signal, is connected to an Arduino microcontroller to convert the data to a digital form using an analog-to-digital converter (ADC). The digital data is then transmitted from the microcontroller to the computer using serial communication. A software running on the computer receives the data and stores it in a data file. Every data file stores the recording of a total of approximately 130 seconds with a sampling frequency of 48 Hz. A snapshot of the sensor is shown below.



The Task

The aim of this assignment is to analyze the relationship between the GSR signal and the physiological response to fear. The GSR data is stored in the csv format. The data contains a total of 2 recordings: one for a fearful experience (stimulated using a fearful VR simulation) and one fearless baseline recording. The assignment involves the following tasks:

1. Develop a function to load the recorded data into a matrix (with 2 columns of data namely the timestamp (in mm:ss:SSS format) and the GSR values (in uS)).

2. Develop a function to implement a 3rd order median filter (median of three neighboring values) to get rid of the spikes from the raw data. Use the filter to process your data by a 3rd order median filter. The function must plot the data before and after filtration.

3. Apply a low pass filter with a passband frequency of 20 Hz. Plot the data before and after filtration.

4. Develop a function to apply an N-point moving average filter. Use the filter to process your data by a 10-point moving average. The function must plot the data before and after filtration.

5. Develop a function to normalize the GSR signal such that the minimum value is zero and the maximum value is 100. Plot the GSR signal against the time axis before and after normalization.

6. Develop a function to determine a total of 10 features about the GSR signal. Read the article below to get more understanding of the terms used in the features

(onset, rise time, amplitude, etc.) (https://connect.tobii.com/s/article/galvanic-skin-response-gsr?language=en_US). The following features should be calculated:

1) Mean of GSR signal (F_1)
2) Variance of GSR signal (F_2)
3) GSR peak rise time sum (F_3)
4) GSR peak amplitude sum (F_4)
5) GSR peak energy sum --> sum(1/2*amplitude*Risetime) (F_5)
6) The amplitude of the highest Skin Conductance Response (F_6)
7) The rise time of the highest Skin Conductance Response (F_7)
8) Number of GSR peaks (F_8)
9) The mean power of GSR signal. (F_9)
10) $$\mathrm{GSR}_{\mathrm{Bwidth}} = \frac{1}{2\pi}\sqrt{\frac{\sum D^2_{\mathrm{GSR}_i}}{\sum \mathrm{GSR}_i^2}}, \quad D_{\mathrm{GSR}_i} = \mathrm{GSR}_i - \mathrm{GSR}_{i-1}$$ (F_{10})

7. Develop a function to use the provided equation to calculate the fear index. Determine the fear index threshold that indicates the presence of fear using the following equation. Where F_i is the feature index as mentioned in the previous step (keep the same order of the features).

$$FearIndex = (F_1 + 2F_2 + F_3 + 0.5F_4 + F_5 + 2F_6 + F_7 + 5F_8 + 0.001F_9 + 0.5F_{10})$$

8. Test your program with the provided data files.

The Software

Develop MATLAB program to implement all the tasks mentioned in the previous section. You may use separate functions (scripts) to implement different tasks. The program must display all the graphs and the fit function as elaborated in the previous section. Note that you do not need to develop test cases for this assignment but you need to test and verify the various tasks using the provided data files (for example, showing the data before and after applying the filter should demonstrate a difference in the noise level). Note also that your solution must be developed in MATLAB (C++ solution will not be accepted).

Write your report using the five steps model for software development (as discussed in class):

a) Step 1: Problem Identification and Statement (5 points)
b) Step 2: Gathering Information (10 points)
c) Step 3: Algorithm (35 points)
d) Step 4: Code or implementation (35 points)
e) Step 5: Results and Analysis (15 points)