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ASSIGNMENT 1

Anaesthesia depth assessment with Spectral Entropy analysis

Assignment
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ABSTRACT

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The content of this report demonstrates the work has been done for Assignment 1 of the course BBT-HTI-501 Processing of Biosignals.

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1. INTRODUCTION

The goal of this assignment is to introduce and have the author to implement a measure for depth of anaesthesia (DOA) using the feature called Spectral Entropy proposed in [1] by H. Viertö-Oja. As a measurement of complexity, the value of Spectral Entropy from a patient is expected to resemble his level of anaesthesia, or more specifically, in a deeper anaesthesia state, one is expected to observe lower value of this feature.

2. METHOD

The assignment was done by first reading the given paper thoroughly to obtain the core content (the Spectral Entropy – discussed in 2.1), investigate the template/premade code and finally implement the required programming.

2.1 Spectral Entropy

Entropy is a concept originated from the field of physics which demonstrates the level of chaos or disorder in a system. From [2], entropy was stated as a statistical measure of the information conveyed by the process. Spectral entropy is the value of entropy computed from the power spectrum of a signal with the following steps:

1. Apply the Fast Fourier Transform (FFT) on the given signal to obtain the spectrum.
2. Obtain the power spectrum of the signal in a pre-determined range of time (epoch) and frequency by taking the square of amplitudes from each element.
3. Normalize the power spectrum with C_n a constant to get the total sum of 1 in the normalized.
4. Compute the spectral entropy $S[f_i, f_2]$ of a frequency range $[f_i, f_2]$.
5. Normalize the computed entropy to $S_N[f_i, f_2]$ by the factor log $N[f_1, f_2]$.

2.2 Given data/function

Data from case1.mat was plotted to get the overview of the signal.

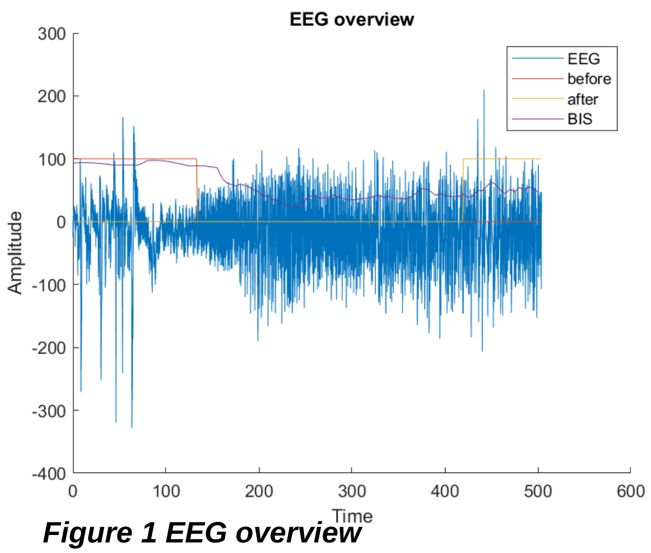

Figure 1 EEG overview

As can be seen from figure 1, the EEG signal contained high frequency component and even with the significant annotation from $before$ and $after$ signals, spotting the begin and awake part of the EEG was still a challenging task.

The sampling rate fs_{eeg} was computed as the mean of sampling frequencies inferred from all consecutive samples. This mean value was 128 and if only the first two samples were chosen, the sampling frequency can be 125.

In the given $entropy\_eeg.m$ file, the Power Spectrum Density (PSD) was computed using the window length of 5 samples and overlap of 50%. The log factor was also obtained.

The required function $spectral\_entropy$ was fed with 2 params: the PSD of the corresponding band and the log factor. The expected output was a $double$ value of spectral entropy DOA for a specific range of time and frequency.

2.3 High pass filter design

Both FIR (order of 300) and IIR (order of 4) filters were tried out, to investigate in this assignment. In both cases, the filters demonstrated the highest suppression in the beginning of the anaesthesia period (80-120 sec) and then during the anaesthetic delivery. To obtain the same level of suppression, the FIR filter requires a much higher order compared with the IIR filter (Figure 2 and 3). Both $highpass$ and $designfilt$ commands from MATLAB were tested and similar results were observed.

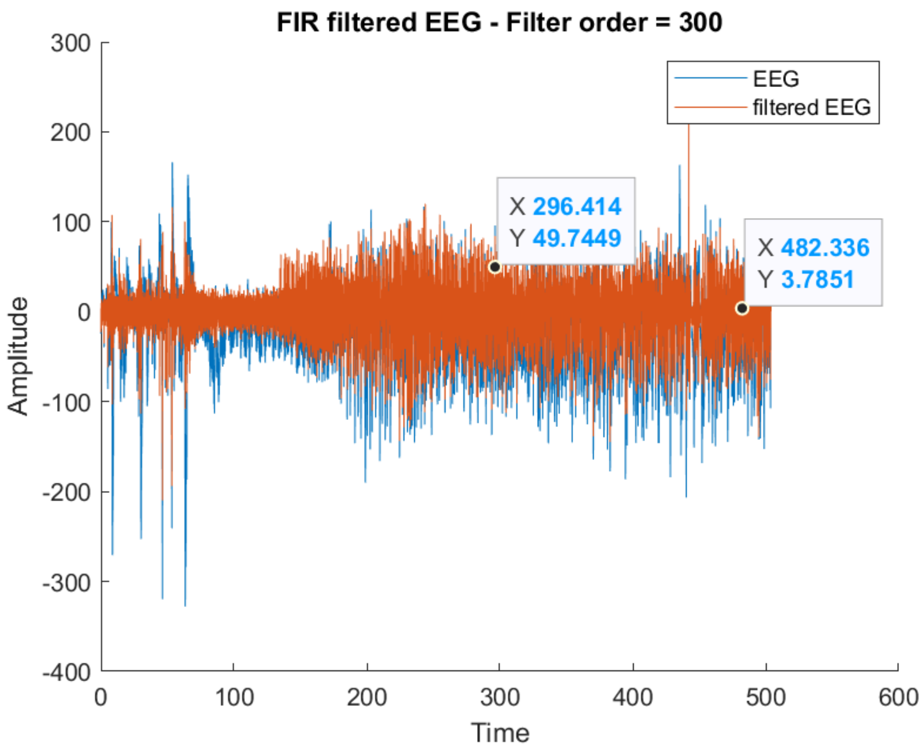

Figure 2 FIR filter (order =300)

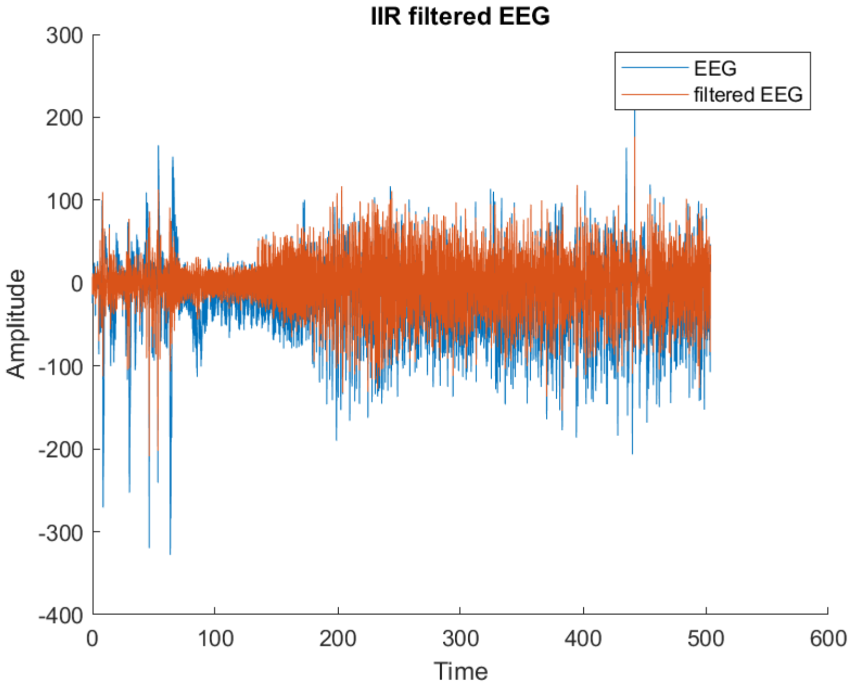

Figure 3 IIR filter (order = 4)

The zero-phase filtering was used, the delay in output signal of the FIR was compensated. In addition, the duration of EEG in this assignment was not long which allowed a high order FIR filter to be operated with acceptable processing time. From these two reasons, the FIR should be taken into consideration in this case, to secure the stability.

2.4 Spectral Entropy DOA

The computation steps were implemented in the order mentioned in part 2.1 with a small difference in the vectorization computation instead of conditional looping. The result can be observed in Figure 4.

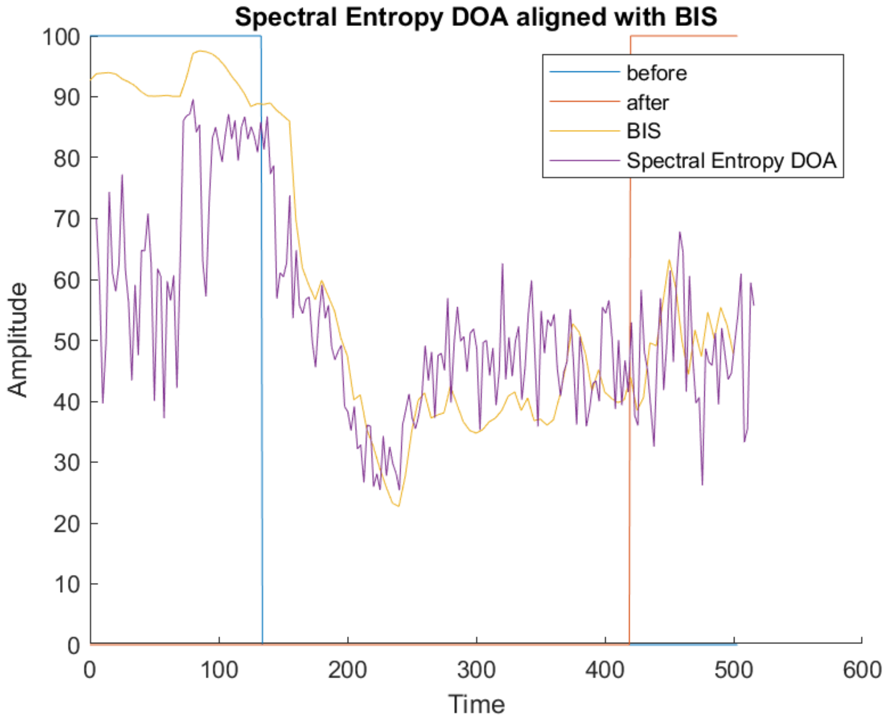

Figure 4 Spectral Entropy DOA aligned with BIS

3. RESULTS AND DISCUSSION

The implemented program integrated well with the given code base and gave the output as can be seen from Figure 4. The value of Spectral Entropy after properly scaling (x100) was aligned with the BIS. This result coincided the expectation that: after the anaesthetic delivery, EEG signal of the patient should contain less ‘disorder’ components hence, we should observe a smaller value of Spectral Entropy DOA. In another word, during the anaesthesia period, the rhythmic activities in the EEG are expected to show us a smaller value of Spectral Entropy DOA.

The final form of Spectral Entropy had a noisy form in comparison with the BIS even we applied the high pass filter on the EEG in advance. We obtained the similar fade-in period compared with the BIS but this is still not a clear indicator for the end of anaesthetic delivery.

4. CONCLUSION

Spectral Entropy DOA is an intuitive parameter to indicate the disorder level of the EEG signal.

The computation steps resemble at a certain level audio processing with the FFT and power spectrum.

There are further enhancement (Time-frequency balanced spectral entropy) and adjustment (State entropy and response entropy) that can be done to bring a great benefit of the constructed feature. [1]

REFERENCES

1. Viertiö-Oja H, Maja V, Särkelä M, Talja P, Tenkanen N, Tolvanen-Laakso H, Paloheimo M, Vakkuri A, Yli-Hankala A, Meriläinen P. Description of the Entropy algorithm as applied in the Datex-Ohmeda S/5 Entropy Module. Acta Anaesthesiol Scand. 2004 Feb;48(2):154-61. doi: 10.1111/j.0001-5172.2004.00322.x. PMID: 14995936.
2. Rangaraj M. Rangayyan PhD, Biomedical Signal Analysis. Wiley, 2015