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BOOKLET

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Title: Metodología para la determinación de patrones en señales electroencefalográficas.

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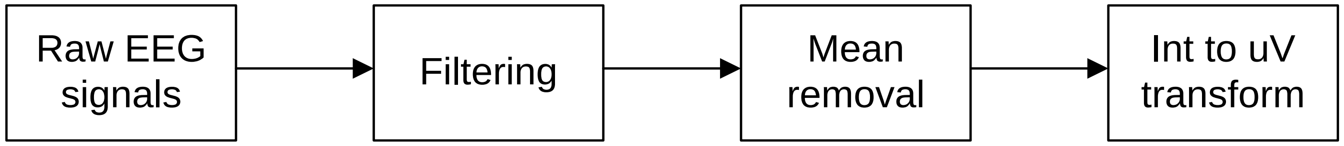
Introduction

- The measurement of the electrical activity of the brain is called electroencephalogram (EEG) and is taken by electrodes placed on the scalp of the subject.
- These electrodes measure the electrical activity of the brain cortex and are placed using a standardized scheme.
- With digital signal processing algorithms is possible to extract features that can describe some thinking patterns and that can be used to control some devices.
- The quality of the patterns is defined by the feature extractions techniques used. There are many kinds of techniques that are widely used nowadays.
- Feature extraction allows extracting more useful or descriptive information hidden in a signal by reducing unnecessary or redundant information.
- Using digital signal processing algorithms is possible to reduce noise, interference, and artifacts before the feature extraction process begins. Once the feature extraction is done, the classification process can be done.

Methodology

- The EEG signals are taken with the Epoc+ via the Emotiv Pro software, which is supplied by the Emotiv company.
- Three EEG one-minute signal register of two people between 22 to 24 years (A and B), thinking first in neutral or relax, then in right and finally in left was taken.
- The signals were recorded seated with their eyes open, one register at the time.
- First, the signal is filtered with a built in 5^{th} order sync digital filter and also with notch filters at 50 Hz and 60 Hz.
- Next, we remove the mean for each channel in order to eliminate de isoelectric line for all the channels.
- Finally, the value obtained is multiplied by 0.51µV (ADC resolution), in order to convert the signal to volts.



Signal Preprocessing

Entropy

- Entropy is a computational complexity sensitive tool that assesses the signal dynamics in a time series data.
- Neural systems are neither completely a random process nor a completely regular one, the measurements of the complexity should have low values for a completely random or a completely regular system.
- Entropy can be used as a simple non-linear feature extraction technique. In this paper Shannon, Log Energy and Normalized Entropies are used.

Coherence

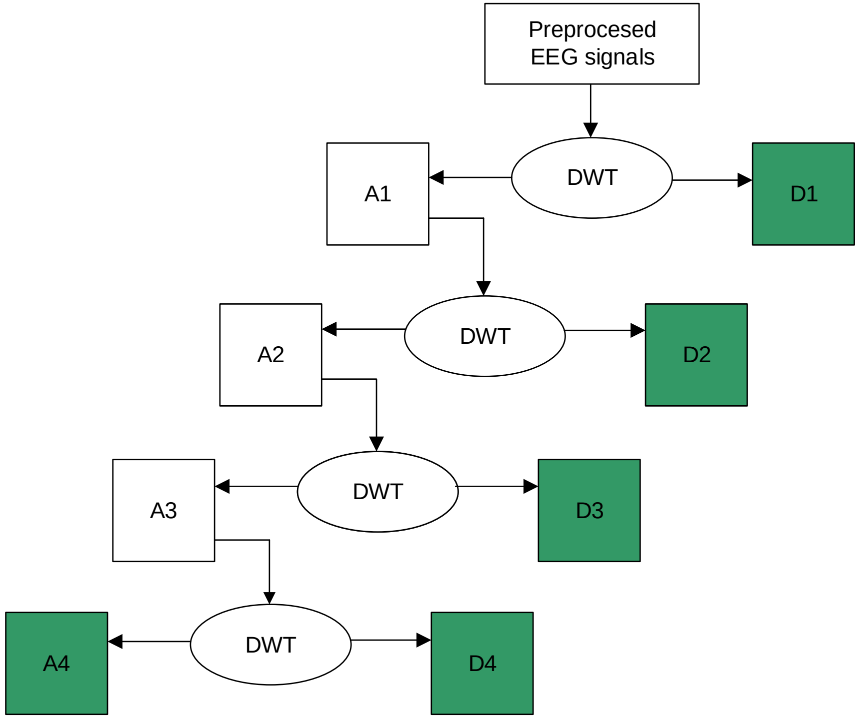
- Coherence is a frequency function, presented in normalized units, that indicates how much the power spectral density of one signal *x(t),* corresponds to the other one *y(t).*
- Coherence is a quadratic correlation coefficient that estimates the consistency of the amplitude and phase related between two signals in a frequency band.
- When the coherence value is 1, this means that the signal *x(t)* totally corresponds to signal *y(t)*, and they are the same signal.

$$\Gamma^2(f) = \frac{\left|S_{xy}(f)\right|^2}{S_{xx}(f)S_{yy}(f)}; \quad 0 \leq \Gamma(f) \leq 1.$$

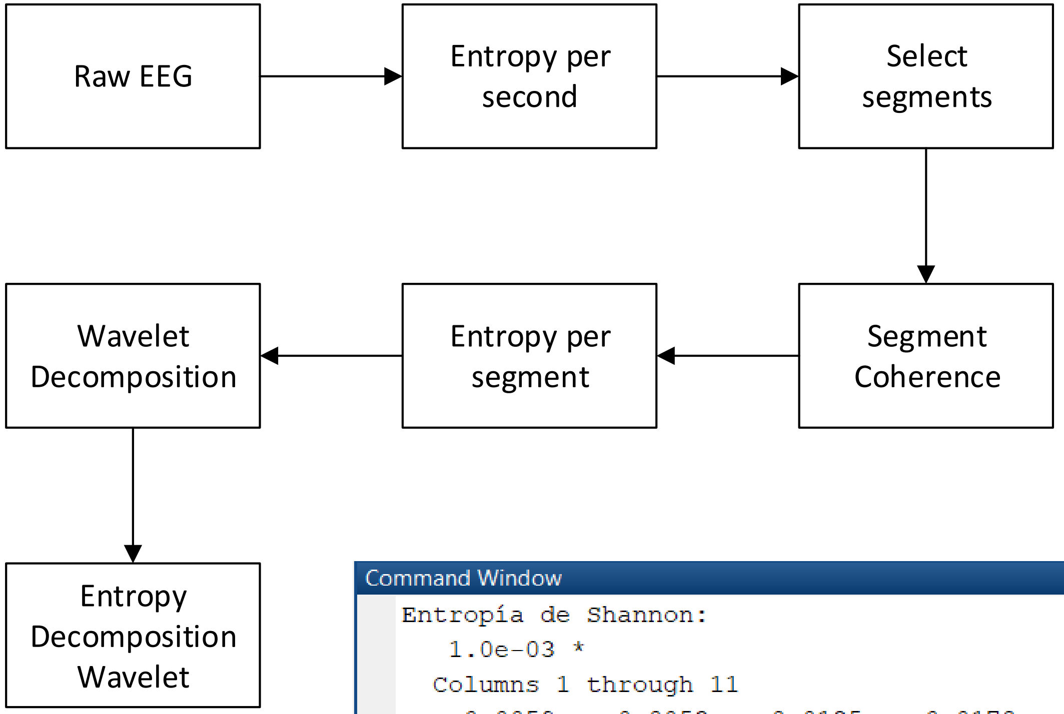
- Any pair of signals can be coherent in some frequency bands and not in another one. In contrast with the amplitude measurements, coherence measures the synchronization between two signals based principally on the phase consistency.
- This represents that if two signals have different phase (as in the common linear simple circuits).
- A high coherence value (near to 1) is presented when the phase difference tends to stay constant.
- For each frequency, the cohere measures when the signals are related one to each other with a linear and time-invariant transformation

Feature Extraction

- First, a visual inspection is made for identifying some possible patterns.
- Then, some segments of the signal containing those possible patterns are taken and then the Entropy and Coherence functions are obtained in order to verify that they have similar levels.
- Then, a four-level Discrete Wavelet Decomposition is done in order to obtain the detailed coefficients (Dx) and the approximated coefficients (Ax).
- Next, the Entropy of the coefficients Dx and Ax are obtained.



Selecting possible patterns



The Shannon, Log Energy and Normalized Entropies of the pair of analyzed segments are obtained in order to verify their relationship.

Subject A, 22 years; Subject B, 24 years.

Command Window

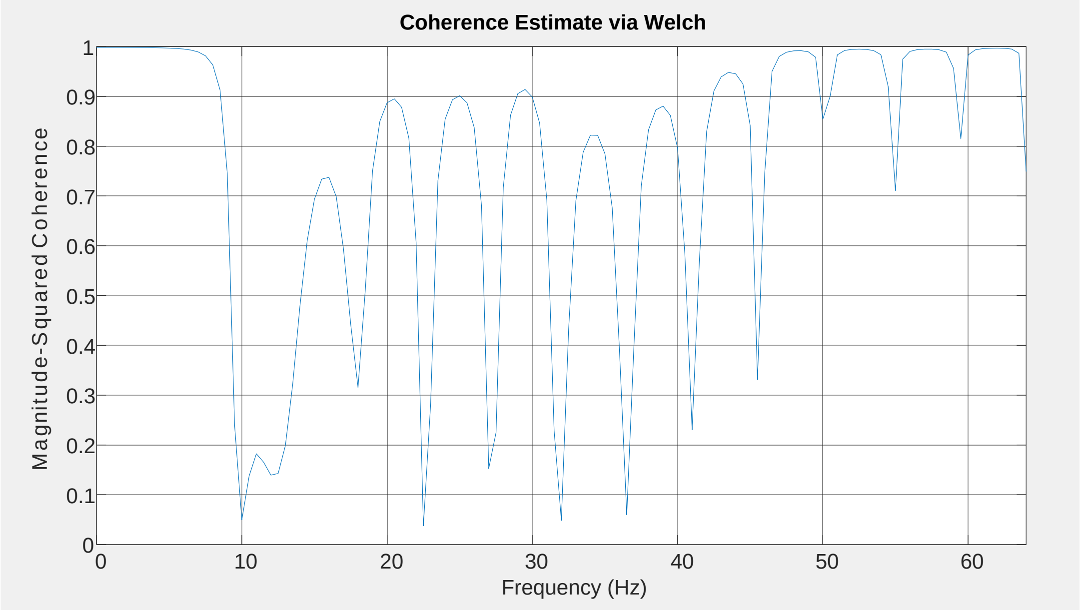
```
Entropía de Shannon:
   1.0e-03 *
  Columns 1 through 11
    0.0059    0.0052    0.0125    0.0178    0.1354    0.2196    0.0495    0.0082    0.0005    0.0014    0.0033
  Columns 12 through 22
    0.0041    0.0034    0.0062    0.0064    0.0068    0.0109    0.0148    0.0109    0.0063    0.0035    0.0032
  Columns 23 through 33
    0.0053    0.0041    0.0313    0.0250    0.0024    0.0026    0.0024    0.0027    0.0126    0.0269    0.0169
  Columns 34 through 44
    0.0195    0.0197    0.0115    0.0077    0.0077    0.0074    0.0066    0.0049    0.0083    0.0058    0.0074
  Columns 45 through 55
    0.0252    0.0264    0.0196    0.0139    0.0109    0.0070    0.0072    0.0091    0.0092    0.0071    0.0086
  Columns 56 through 60
    0.0071    0.0067    0.0051    0.0052    0.0054
Entropía Log Energy:
   1.0e+03 *
```

Experiments in user A (Entropies)

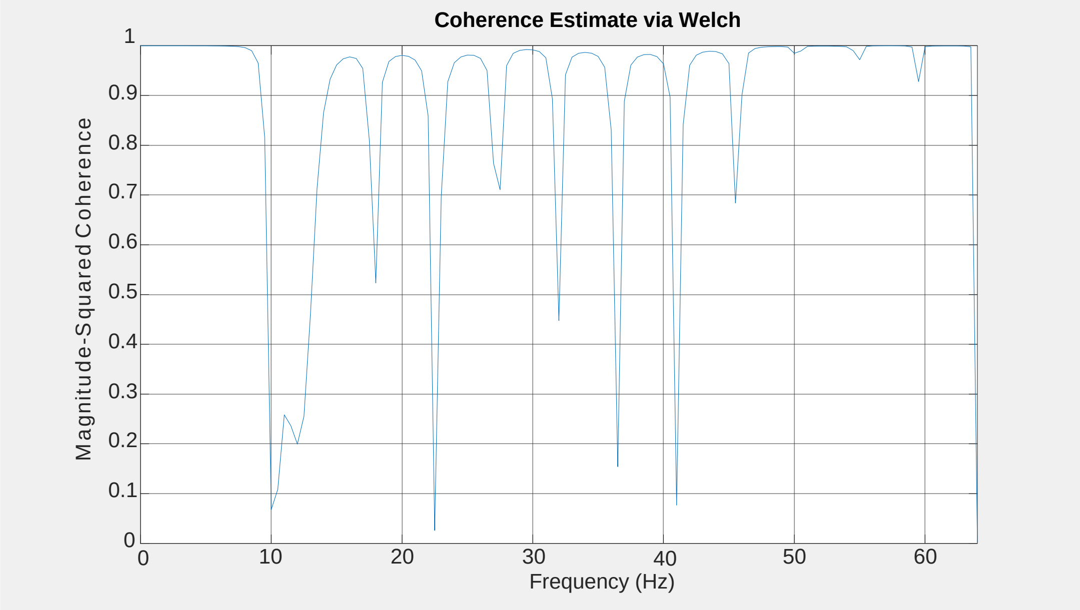
Channel Time	Entropy (Shannon)	Entropy (Log Energy)	Entropy (Norm)
AF3 8s & 33s	6.0682e-05 5.9660e-05	-2.2483e+03 -2.2509e+03	0.0089 0.0088
O1 14s & 15s	0.0062e-4 0.0064e-4	-2.5391 -2.5344	0.0023 0.0024

Channel	Entropy (Shannon)	Entropy (Log Energy)	Entropy (Norm)
F4 8s &23s	0.2732e-03 0.2717e-03	-2.0248e+03 -2.0255e+03	0.00213 0.0213
T8 18s & 21s	5.7666e-05 5.1997e-05	-2.2552e+03 -2.2694e+03	0.0086 0.0081

We can notice that are kind of similar values are obtained.



AF3, left test



F4, right test

Experiments in user A (Wavelet Entropy)

Electrode AF3	D3 (Entropy)		
	Shannon	Log Energy	Norm
8 sec.	5.8756e-09	-430.9594	1.2347e-05
33 sec.	1.3581e-08	-398.1880	2.4502e-05

Shannon entropies are different, but Log Energy and Normalized entropies for the Detail coefficients are closer.

Shannon and Normalized entropies are quite different, but the Log Energy ones are similar.

Electrode AF3	D4 (Entropy)		
	Shannon	Log Energy	Norm
8 sec.	2.6990e-09	-204.8071	7.3692e-06
33 sec.	8.9709e-09	-198.3364	1.4654e-05

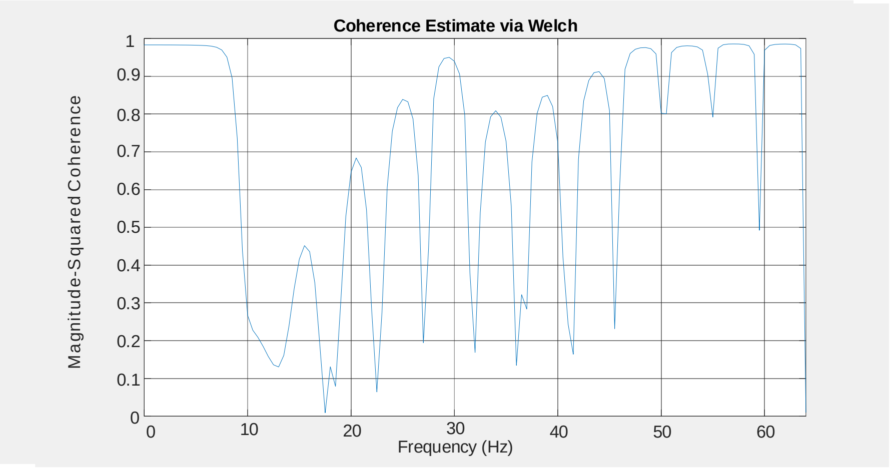
Electrode AF3	A4 (Entropy)		
	Shannon	Log Energy	Norm
8 sec.	5.6674e-05	-131.9524	0.0028
33 sec.	5.6309e-05	-132.0304	0.0028

The entropies are similar and these entropies are different from the ones obtained using only the one-second data segments.

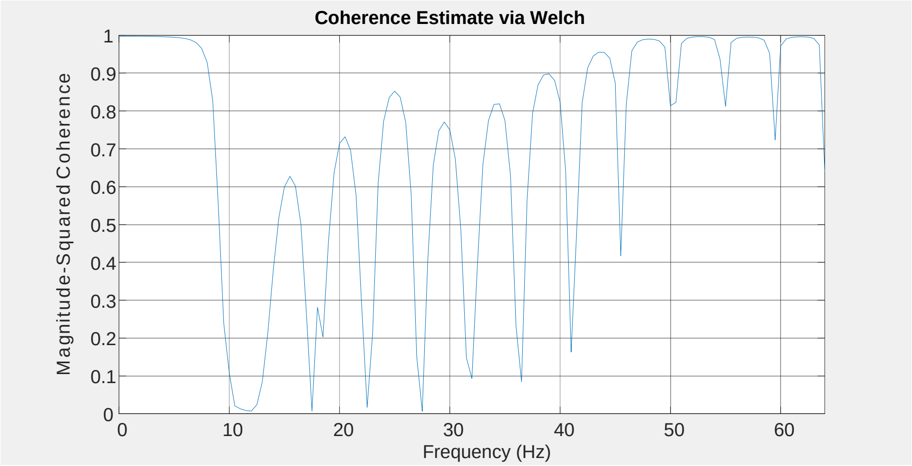
Experiments in user B (Entropies)

Channel Time P7	Entropy (Shannon)	Entropy (Log Energy)	Entropy (Norm)
23 s	4.7741e-05	-2.2812e+03	0.0077
52 s	9.8571e-05	-2.1871e+03	0.0117

Electrode Time	Entropy (Shannon)	Entropy (Log Energy)	Entropy (Norm)
T8 55s & 56s	5.2676e-05 5.4524e-05	-2.2680e+03 -2.2633e+03	0.0082 0.0083
F3 7s &36s	2.7070e-05 2.7018e-05	-2.3600e+03 -2.3600e+03	0.0055 0.0055



P7, Subject B, right test



T8, Subject B, left test

Experiments in user B (Wavelet Entropy)

Closer entropy values were obtained for the Log Energy and the Normalized entropies.

Electrode	D3 (Entropy)		
P7	Shannon	Log Energy	Norm
23 sec.	1.4247e-08	-405.1969	2.3961e-05
52 sec.	2.2473e-08	-386.3170	3.4070e-05

Electrode	D4 (Entropy)		
P7	Shannon	Log Energy	Norm
23 sec.	8.7090e-09	-200.0164	1.2708e-05
52 sec.	5.0026e-08	-186.9553	3.8515e-05

These entropies values are discrepant. The closer ones are Log Energy, but there are not too similar.

It can be observed that Log Energy and Normalized Entropies got closer values.

Electrode	A4 (Entropy)		
P7	Shannon	Log Energy	Norm
23 sec.	4.4841e-05	-134.2122	0.0025
52 sec.	9.5113e-05	-127.3002	0.0038

Conclusions

- We observe that the methodology presented is useful to determine the confidence of the possible pattern.
- Sometimes, using the entropies and cohere functions directly to the preprocessed signal does not reflect the real significance of the possible pattern.
- Working with the entropies of the coefficients of the Discrete Wavelet Transform is useful to validate the possible pattern.
- In this case, the Log Energy and the Normalized entropies gave closer values, so they had better performance.

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