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Quantification and comparison of Different Non-Linear techniques of EEG signals

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Abstract - *The research thesis focused on evaluation and comparison of various non-linear techniques for the analysis of EEG signals acquired while performing mental task. For the study, EEG signal of subject was recorded while performing job on solid works. EEG signal is studied by evaluating the nonlinear parameters like Approximate Entropy, Fuzzy Entropy, Sample Entropy. Borg scale is used for the evaluation of perceived exertion on the scale of 6-20. The study focused on the comparison of nonlinear techniques so as to find to most relevant one to express the mental exertion of worker while performing job on design software. Also, to find the most sensitive node of brain. The study concluded that Brain Node O1-O2 gave the most relevant and best results as compared to other 5 nodes of brain for the prediction of exertion during task. Study also concluded that Fuzzy entropy provides the most relevant approach for study of mental exertion, followed by sample entropy and then approximate entropy. Therefore, we can say that fuzzy entropy can be considered as a parameter to judge the level of mental exertion during the period of task.*

Key Words: **EEG, Approximate Entropy, Fuzzy entropy, Sample Entropy, Perceived exertion**

1.INTRODUCTION

Electroencephalography (EEG) is an electrophysiological monitoring technique for the recording of electrical activity of the brain, which is recorded simultaneously at many locations by one electrode placing at each position on the human scalp. Electrodes are placed with a conductive gel or paste on scalp. EEG measures voltage potential resulting from ionic current within the neurons of the brain. EEG refers to the recording of the spontaneous electrical activity over a period of time.

In case of EEG Electrodes are affixed to the skull with conductive gel. The standard placement recommended by the American EEG society for use in the International 10-20% system is for 21 electrodes. The standard numbering system in the 10-20 system places odd-numbered electrodes on the left and even numbered electrodes on the right, with the letter designating the anatomic area. It provides the relationship between the position of an electrode and the area of cerebral cortex beneath. There are 5 lobes of brain. F, C, T, O and P stand for frontal, central, temporal, occipital and parietal lobes. Odd number assigned to any lobe refer to the left hemisphere whereas, even numbers refer to the right hemisphere. "z" (zero) refers to an electrode placed on the midline. The letter codes Fp identify the frontal polar location.

Linear analysis of EEG signals includes frequency analysis (e.g. Fourier and Wavelet Transforms) but it they only provide a limited amount of information. These ignore the underlying nonlinear EEG dynamics. The electrical activity of a brain measured by Electroencephalogram (EEG) exhibits complex behavior with non-linear dynamic properties. This behavior takes the form of EEG patterns with different complexities. Considering this, the nonlinear dynamics theory may be a better approach than traditional linear methods in characterizing the intrinsic nature of EEG. The study of nonlinear dynamics and characterization can contribute to the understanding of the EEG dynamics and underlying brain processes.

In this work, EEG is recorded for Subject doing mental task of perform job on solid works. EEG signal is studied by evaluating the nonlinear parameters like Approximate Entropy, Fuzzy Entropy, Sample Entropy. Then we perform the comparison of various parameters with perceived exertion calculated on Borg scale of 6-20 on the basis of slope of linear regression Trend lines. So as to provide the most relevant brain node and parameter for EEG signal analysis.

2. METHODOLOGY

The purpose of the study is to perform the comparison of various nonlinear techniques (Approximate Entropy, Fuzzy Entropy, Sample Entropy, Hurst exponent and Lyapunov exponent) so as to find to most relevant one to express the mental fatigue of workers while performing job on design software. Purpose is also to find the most sensitive node of brain and to find the node which will provide best results for the prediction of mental exertion during task. For this purpose, assembly job Pipe Vise on solid works design tool, is selected.

There was an assembly job of pipe vise on solid works. Drawing of different views of pipe vise is provided to the subjects in hard copy format. 13 Subjects were allowed to perform assembly of pipe vise by part wise approach. Subjects were allowed to perform for 8 hours shift. They were provided with break of 10 minutes after each reading. Then there was a lunch break of 60 minutes. Evening session starts after lunch break. Evening session also consist of four working hours with rest of 10 minutes after each readings. Brain nodes were finalized and connected on the basis of bipolar montage. 6 nodes were finalized. Those 6 nodes were-

1) T3-T4 (temporal lobe) 2) P3-P4 (parietal Lobe) 3) O1-O2 (occipital lobe) 4) Fp1-Fp2 (fronto-Parietal Lobe) 5) F3-F4 (frontal lobe) 6) Fz-Pz (central lobe). Nodes are according to 10-20 system.

For comparison 3 Non-Linear techniques were finalized. Those 3 Nonlinear techniques are Approximate Entropy, Sample entropy, Fuzzy entropy.

3. ANALYSIS

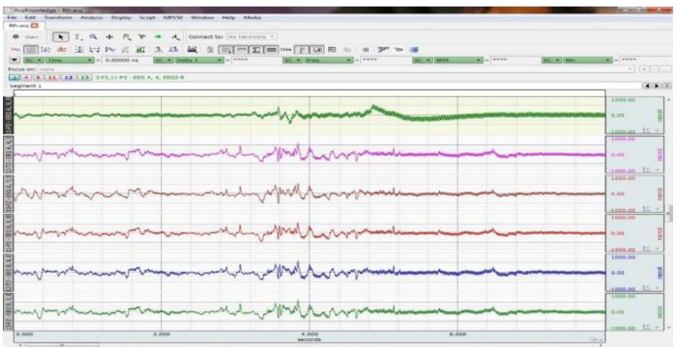
Reading was taken by using BIOPAC MP 150 Hardware tool and Acquisition 4.3 Software. Voltage generated by the brain node first goes to the transmitter and transmitter transmits the signal to the receiver, receiver also amplifies the weak signals.

Some initial calibration of the machine is required for the recording of EEG signals. Thus, initial setting of machine is important so as to get proper manner of required signal. Few frequency filters are required to set according to the requirements of experiment. Calibration of machine is given below-

Calibration of Machine (Table 1)

Item	Range
Sample rate/ frequency	1000 samples/ sec.
Acquisition Length	60 seconds
Low pass filter	50 Hz
High pass filter	0.1 Hz

After that signals are record with the help of computer as shown in the figure 1



EEG Signal sample for 6 brain lobes (Figure 1)

The signals for different nodes of brain provided by EEG software are processed by feeding it as an input for MATLAB. MATLAB processed those signals according to the codes of various non-linear techniques so as to give output of parameter at every point of time series for each node of brains.

A MATLAB codes of Approximate entropy, Fuzzy entropy, Sample Entropy has been made to process the signal.

Rating of perceived exertion (RPE) is a reliable indicator and very widely used tool for monitoring of intensity of work. The scale allows subject to rate his own level of exertion during task. Borg Scale is developed by Gunnar Borg. Despite Scale is a subjective measure of intensity of work, still it provides very good valuable information when used in correct manner. I here used category scale of rating of perceived exertion. It is 6 to 20 scale.

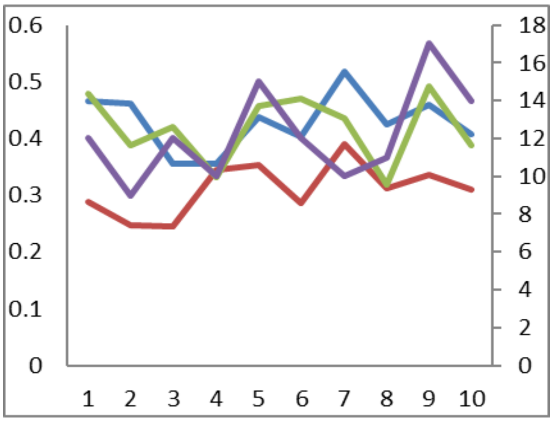
While performing experiment, subjects' rate there level of exertion in the beginning of the experiment and before all the breaks and the end of the experiment in the evening. Rating task was performing before each break of 10 minutes and at the start of second session after lunch break.

3. RESULT AND DISCUSSION

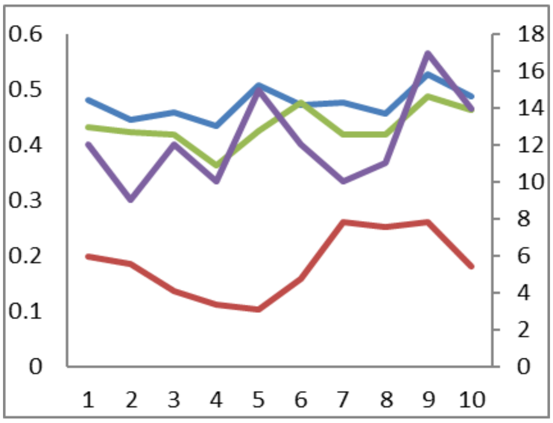
Charts were generated for each brain node differently for 13 experiments on 13 subjects. Perceived exertion rating is also shown by perceived exertion line on these charts.

By comparison on the basis of slope of these charts we can easily recognize which node and which non-linear techniques provide more relevant, more accurate and more sensitive results when compared with each other and with perceived exertion. Resultant charts of each node for one of the 13 experiments is shown in figure 2

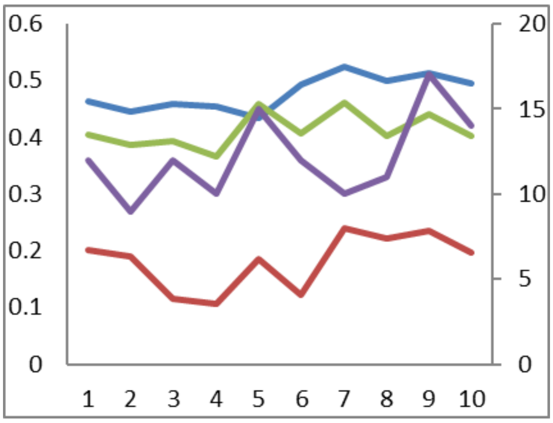
Chart showing variation of approximate entropy, fuzzy entropy, sample entropy and perceived exertion. Primary Y-axis represent the values of various entropies, secondary Y-axis represent the rating of perceived exertion and X-axis represent the time. 10 points on X-axis represent the 10 time intervals at which reading was taken in whole working day as explained under experimental protocol guidelines in earlier chapters.



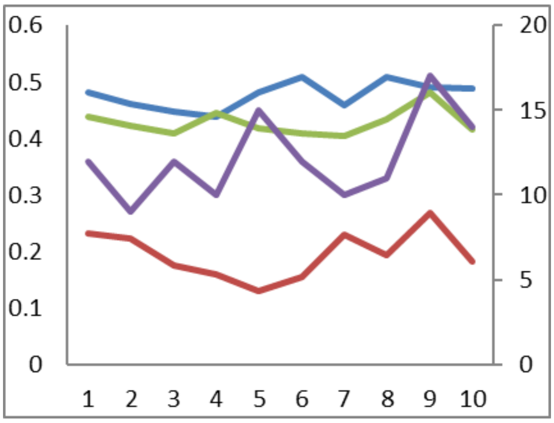
F3-F4



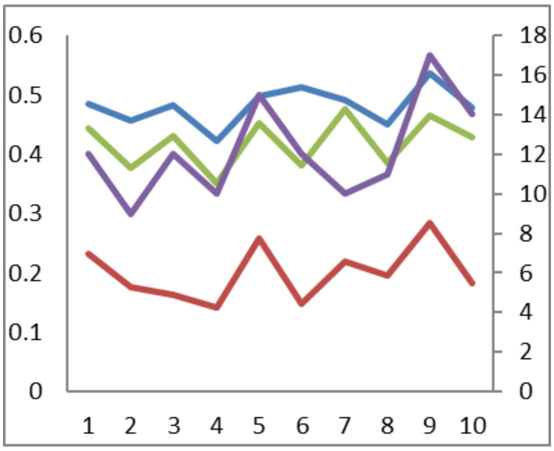
O1-O2



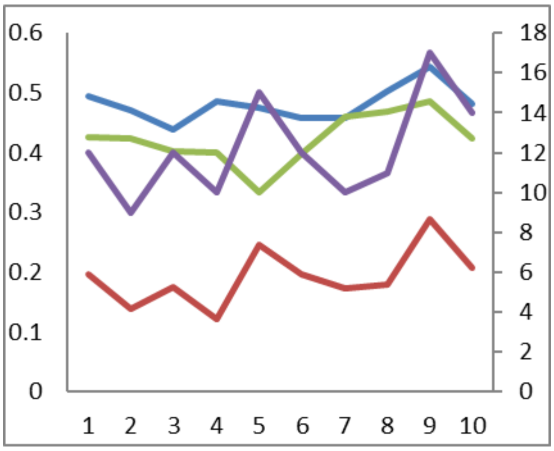
FP1-FP2



P3-P4



T3-T4



Fz-Pz

Variation of entropies with perceived exertion for experiment (Figure 2)

Comparison is done on the basis of Slope for each entropies and perceived exertion. Linear regression Trend lines are drawn for each of the 3 entropies and perceived exertion. Then slope of these lines was calculated for each brain node. Table of slope representing slope of approximate, fuzzy, sample entropy best fit lines for each node is given below. Perceived exertion best fit line Slope remain same for every brain node.

Value of Slope for entropies and perceived exertion for experiment (Table 2)

Brain node	approximate	fuzzy	sample	Perceived exertion
F3-F4	0.0005	0.003	0.0003	0.0111
O1-O2	0.0015	0.0122	0.0061	0.0111
Fp1-Fp2	0.003	0.0096	0.0056	0.0111
P3-P4	0.0026	0.0085	0.0061	0.0111
T3-T4	0.0023	0.0135	0.0002	0.0111
Fz-Pz	0.0066	0.0095	0.0002	0.0111

13 such experiments were performed on 13 different subjects and charts were generated for each one of them for 6 brain nodes. Then slope for linear regression trend line of each parameter and perceived exertion was calculated.
Results of 13 experiments conducted to provide the most relevant Node and Entropy for the prediction of exertion during work is given below. This is done by comparing approximate entropy, Fuzzy entropy and sample entropy with the rating of perceived exertion on the basis of slope of linear regression trend lines drawn for each parameter on chart.

Results of 13 experiments on basis of comparison of slope (Table 3)

Experiment No.	Node	Interpretation of Entropy
1	O1-O2	Fuzzy > Sample > Approximate
2	O1-O2	Fuzzy > Approximate > Sample
3	Fz-Pz	Sample > Fuzzy > Approximate
4	O1-O2	Fuzzy > Sample > Approximate
5	O1-O2	Sample > Fuzzy > Approximate
6	Fz-Pz	Fuzzy > Sample > Approximate
7	O1-O2	Fuzzy > Sample > Approximate
8	Fz-Pz	Fuzzy > Sample > Approximate
9	O1-O2	Sample > Fuzzy > Approximate
10	O1-O2	Fuzzy > Sample > Approximate
11	O1-O2	Fuzzy > Sample > Approximate
12	O1-O2	Fuzzy > Sample > Approximate
13	Fz-Pz	Sample > Fuzzy > Approximate

4. CONCLUSIONS

Conclusions drawn from the comparison of entropies with perceived exertion are given below

1) Out of 13 experiments conducted, 9 experiments concluded that Node O1-O2 gave the most relevant and best results as compared to other 5 nodes of brain for the prediction of exertion during task.

2) 9 out of 13 experiments concluded that Fuzzy entropy provided the most relevant approach for study of mental exertion, followed by sample entropy and then approximate entropy.

Therefore we can say that fuzzy entropy can be considered as a parameter to judge the level of mental exertion during the period of task.

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