Generation, Filtering and Feature Extraction of Electroencephalogram (EEG) Signals

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***Abstract*-The recording of electrical activity of brain is called as Electroencephalogram (EEG). EEG is the measure of voltage fluctuations resulting from ionic current flows within the neurons of the brain.This paper focus on generating EEG signals using an Event Related Potentials (ERP) of phase-resetting method [1], preprocessing using Savitzky–Golay (S-G) Filter and Feature Extraction.Inphase-resetting method, the experimental eventsreset the phase of ongoing oscillations. S-G Filter is used to reduce the effect of noise on original signal.S-G Filter [2] is a smoothing filter andalso called digital smoothing polynomial filter.It is mainly used to "smooth out" a noisy signal whose frequency span is large.Feature Extractionof EEG signals is core issues in EEGsignal analysis. Feature Extraction [3] is done to extract prominent key features and to reduce the dimension of feature space.Different features show different discriminative power for different subjects or different trials. In this paper, multi-features are used to improve the performance of EEG signals.**

Keywords: EEG, ERP, S-G Filter and Feature Extraction

I. INTRODUCTION

The EEG signal is refer to the recording of the brain's spontaneous electrical activity over a short period of time, usually 20–40 minutes. It is recorded from multiple electrodes placed on the scalp. EEG is a record of the electrical potentials generated by the cerebral cortex nerve cells. The recording EEG signals from the brain using Brain Computer Interface [5] is very complex.The recorded signals are hugeand have more artifacts than required information data.This data is very large and difficult to process in real time.By using phase resetmethod, a random frequency sinusoid signal whose phase is being reset is generated.

Savitzky-Golay Filter is used to reduce the effect of noise on original signal. It is a low-pass filter which is suitable for smoothing data in time series.Feature extraction is a special form of dimensionality reduction. When the input data to a system is too large to be processed and it is suspected to be redundant in all the parameters, then the input data will be transformed into a reduced representation set of features. Transforming the input data into the set of features is called Feature Extraction.If the features extracted are carefully chosen it is expected that the features set will extract the relevant information from the input data in order to perform the desired task using this reduced representation instead of the full size input. Feature extraction involves simplifying the amount of resources required to describe a large set of data accurately.

This paper describes generation of EEG signal, filtering using S-G Filter and Feature Extraction. Plot of EEG signal, filtered signal and their comparison is shown, also Feature Extraction result and the plot of each of its parameter is discussed.

II. EEG SIGNAL GENERATION

EEG data is generated by an Event Related Potentials (ERP) [4] of phase-resetting method. Function phase-reset allows simulate a sinusoid whose phase is being reset. In the phase-resetting theory the experimental events reset the phase of ongoing oscillations. Function phase-reset allows generating a sinusoid whose phase is being reset.

Function (frames, epochs, sampling-rate,4,16,position), the first three parameter of this function, are the same as for peak and noise. The next two parameters define the minimum and maximum frequency of the oscillation -on each trial the oscillation is generated by choosing a random number from this range. The fifth parameter defines the frame in which the reset should occur. The initial phase of the oscillation is chosen randomly.

III. SAVITZKY-GOLAY FILTER AND DESIGN

Savitzky - Golay Filter is a method of datasmoothing based on local least-squares polynomial approximation. It shows that fitting a polynomial to a set of inputsamples and then evaluating the resultingpolynomial at a single point withinthe approximation interval is equivalentto discrete convolution with a fixedimpulse response. The low pass filtersobtained by this method are widely known as Savitzky-Golay filter. S-G Filter is also used for detection of spikes.

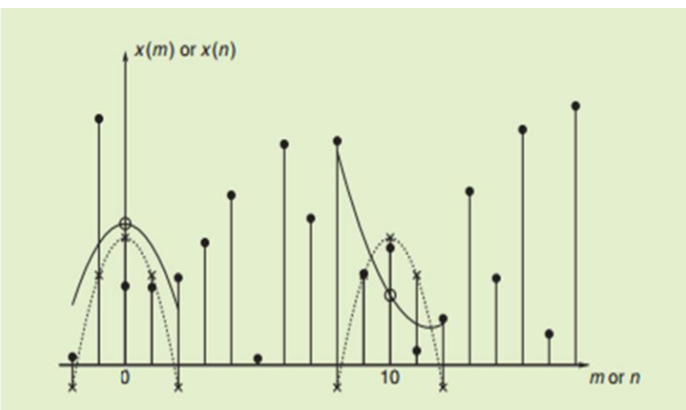

Fig.1. Illustration of least-squares smoothing by locally fitting a second-degree polynomial (solid line) to five input samples: ●denotes the input samples, ○ denotes the least-squares output sample, and × denotes the effective impulse response samples (weighting constants). (The dotted line denotes the polynomial approximation to centered unit impulse.

Consider a sequence of samples x[n] of a signal as solid dots. Considering for the moment the group of 2M+1 samples centered at n=0, obtain thecoefficients of a polynomial:

$$p(n) = \sum_{k=0}^{N} a_k n^k \quad (1)$$

The coefficients $a_0, a_1, a_2 \ldots\ldots, a_k$ are obtained by solving the normal equations.The i^{th}row of the Jacobian Matrix,$J = \frac{\partial y}{\partial x}$,has values 1,n, n^2,…….n^k.

This minimize the mean-squared approximationerror for the group of inputsamples centered on n=0.

$$\epsilon_N = \sum_{n=-M}^{M} (p(n) - x[n])^2 \quad (2)$$

$$\sum_{n=-M}^{M} \left(\sum_{k=0}^{N} a_k n^k - x[n]\right)^2 \quad (3)$$

The solid curve in the Figure1 is the polynomial p(n) evaluated on a fine grid between -2 and +2, and the smoothed output value is obtained by evaluating p(n) at the central point n=0.

That is, y [0], the output at n=0, is

$$y[0] = p(0) = a_0 \quad (4)$$

The output value is just equal to the 0^{th} polynomial coefficient. In general, the approximation interval need not besymmetric about the evaluation point.This leads to nonlinear phase filters.

This can be useful for smoothing at the ends of finite-length input sequences.The output at the next sample is obtainedby shifting the analysis intervalto the right by one sample, redefiningthe origin to be the position of the middlesample of the new block of 2M+1 samples, and repeating the polynomialfitting and evaluation at the central location.This can be repeated at eachsample of the input, each timeproducing a new polynomial and a newvalue of the output sequence y[n].

IV. DATA DESCRIPTION

The required dataset for the Feature Extraction is generatedby usingan Event Related Potentials (ERP) of phase-resetting method in MATLAB. In phase-resetting method, the experimental events are reset the phase of ongoing oscillations. ThenElectroencephalogram (EEG) signal is filtered by using Savitzky–Golay(S-G) Filter. EEG is signal is nothing but time series signal with varying frequency in regular time interval. The (EEG) is a recording of the electrical activity of the brain from the scalp. The recorded waveforms reflect the cortical electrical activity. The signal intensity of EEG is quite small and measured in micro volts (mV).

V. METHODOLOGY

EEG signal is generated by usingan Event Related Potentials (ERP) of phase-resetting method and generated signals are filteringby using S-G Filter and Featuresare extracted based on mathematical calculations like Average, Maximum, Minimum, Standard deviation and Variance.

A. EEG Signal Generation:

EEG Signals are generated using Matlab. Function phase-reset allows generating a sinusoid whose phase is being reset. 10 different EEG signals are generated; one such EEG signal generated has inputs defined as: frames-300, epoch-1, sampling rate-100Hz and position-150, with frequencies chosen randomly from range 4Hz-16Hz. The oscillation is generated by choosing a random number from this range and position describes the frame in which the reset should occur. The initial phase of the oscillation is chosen randomly.EEG signal generated using this data is shown in figure 3.

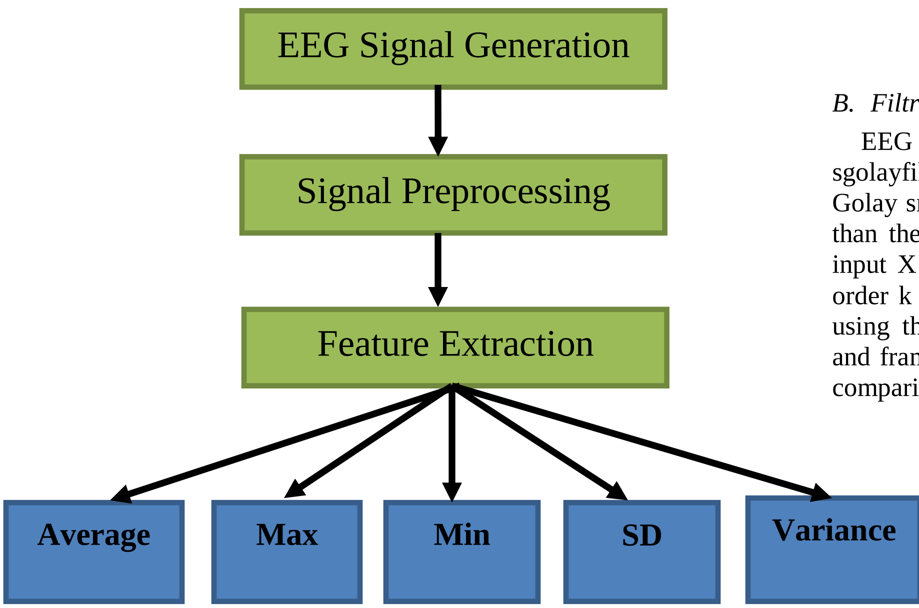

Fig.2. Proposed Methodology

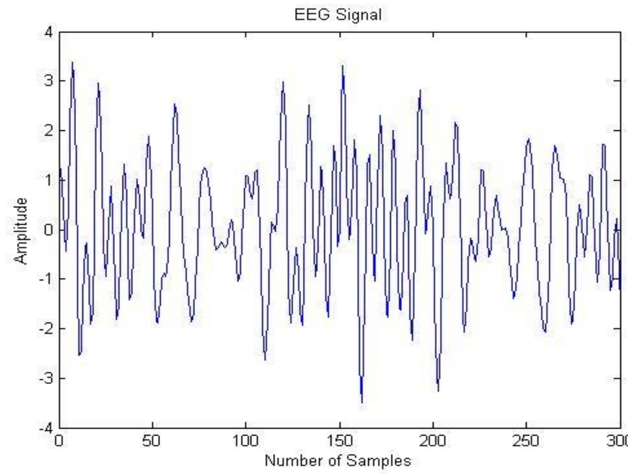

Fig. 3.EEG Signal

B. Filtration:

EEG signal is pre-processed using Savizky-Golay Filter, sgolayfilt (X,K,F) smoothest the signal X using a Savitzky-Golay smoothing filter. The polynomial of order Kmust be less than the frame size, F, and F must be odd. The length of the input X must be greater than or equal to F. If the polynomial order k equals f-1 then no smoothing occurs. Signal is filtered using the parameters: generated signal-X, polynomial order-2 and frame size-9. Filtered signal is shown in figure 4 and their comparison in figure 5.

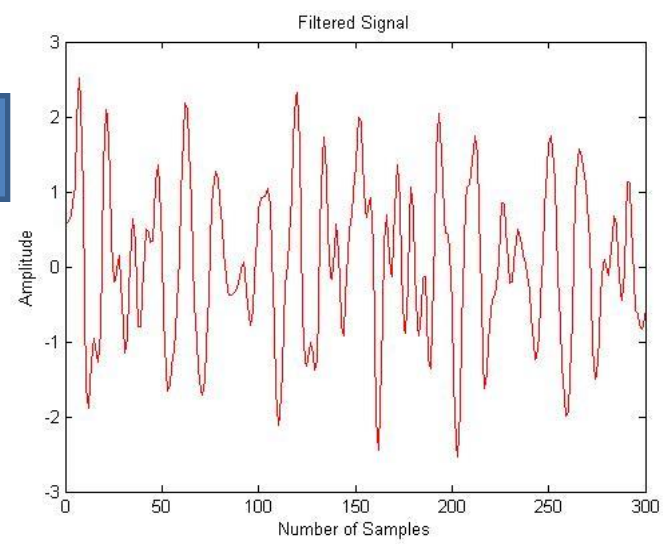

Fig. 4.Filtered Signal

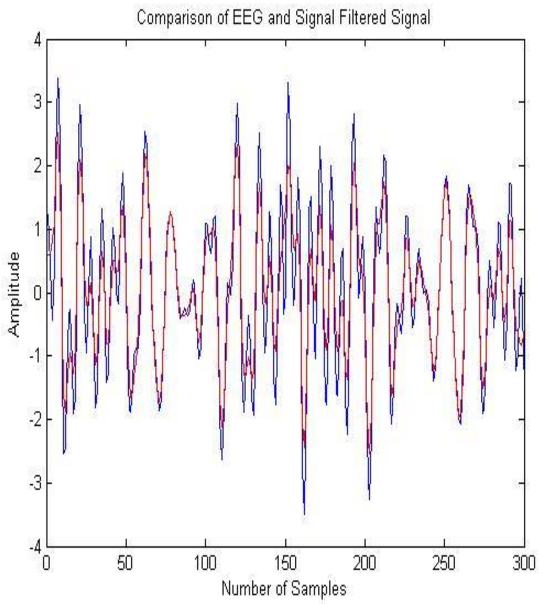

Fig. 5. Comparison of EEG and Filtered Signal

C. Features Extraction

When the input data to an algorithm is too large to be processed and it is large data, but not much information, then the input data will be transformed into a reduced representation set of features. Transforming the input data into the set of features is called feature extraction.The features are extracted based on the parameters like Average, Maximum, Minimum,Standard Deviation and Variance methods.

The main purpose of feature extraction is for prediction performance in classification. Feature extraction may improve over all domain understanding. Analysis of large data generally requires a large amount of memory and computational power or a classification algorithm which generalizes poorly to new samples by over fitting the training sample. Feature extraction is a general method for constructing combinations of the variables in order to get around these problems while still describing the data with sufficient accuracy.

*1) Average Method:*Average is defined as the sum of 'x' data sets divided by 'N' total number of data sets. It is called the mean average.

$$\text{Average} = \sum \frac{x}{N}$$

Where, x is data

N is total number of datasets

*2) Maximum Method:*The maximum is defined as the greatest quantity or the greatest value attainable in a given data sets.

Max = maximum(x1, x2, x3, x4……….xN)

*3) Minimum Method:*The Minimum is defined as the lowest quantity or the lowest value attainable in a given data sets.

Min = minimum(x1, x2, x3, x4………xN)

*4) Standard Deviation:*Standard Deviation is defined as the how much variation or "dispersion" exists from the average, mean or expected value.

$$SD(\sigma) = \sqrt{\frac{(x-\mu)^2}{N}}$$

Where, σ= Symbol of Standard Deviation
μ = mean of all the values in the data set
N = Total Number of values in data set
x = each value in the data set

*5) Variance (σ^2):*Variance is defined as the square of standard deviation or the variance of a random variable.

$$\text{Variance}(\sigma^2) = SD^2 = \sum \frac{(x-\mu)^2}{N}$$

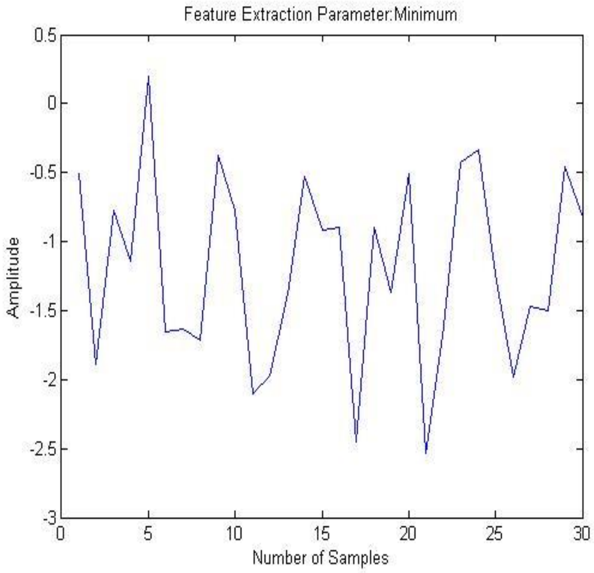

Fig. 6. Feature Extraction Parameter: Minimum

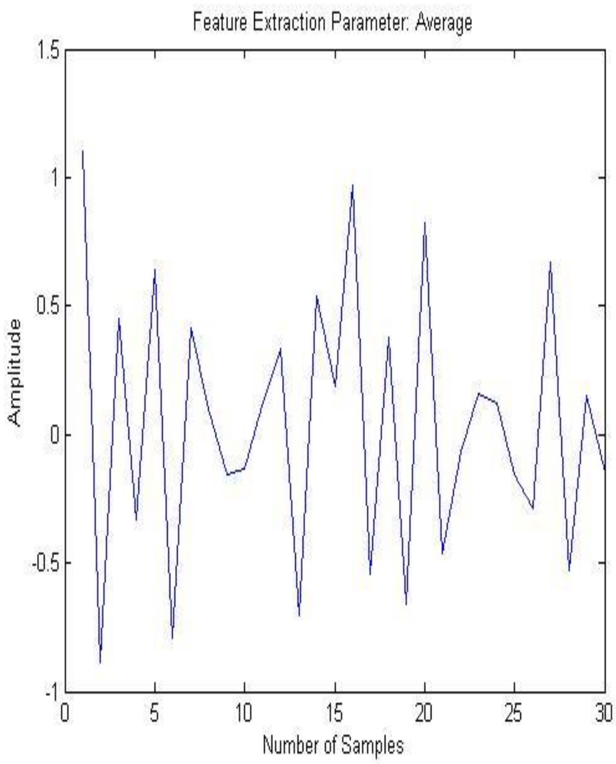

Fig. 7. Feature Extraction Parameter: Average

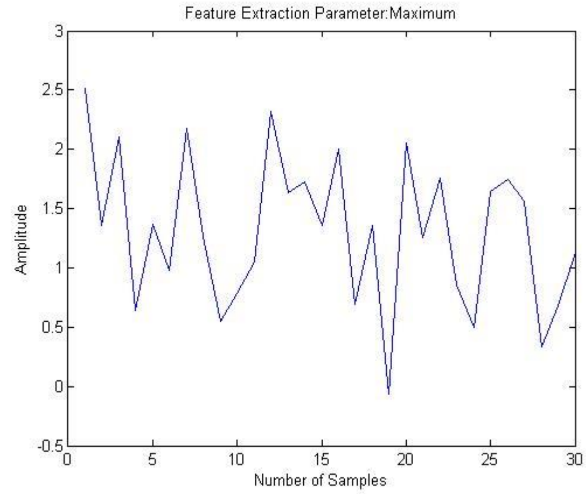

Fig. 8. Feature Extraction Parameter: Maximum

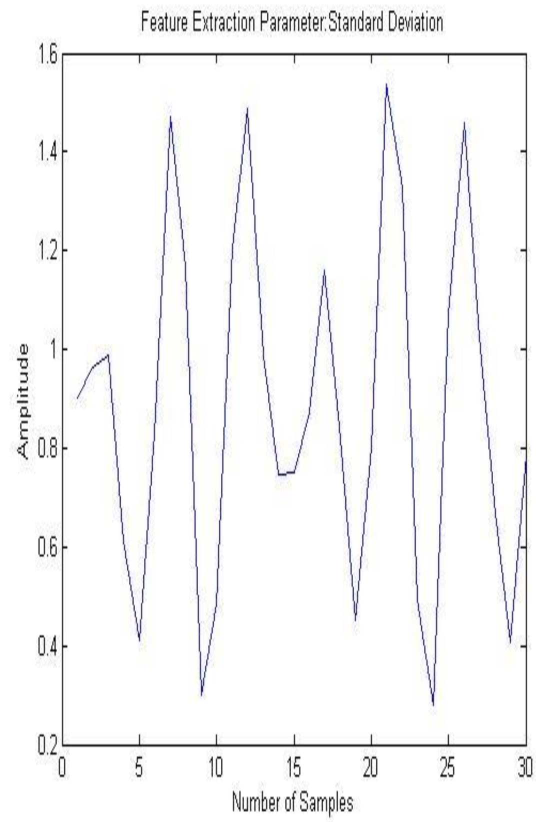

Fig. 9. Feature Extraction Parameter: Standard Deviation

VI.RESULTS

Features are extracted based on mathematical calculations like minimum, mean, maximum, standard deviation and variance.The input signal size is 300 samples, the features are extracted for an interval of every 10 samplesso at the end there will be 30 featuresextracted from each signal. Totally 30 * 5=
150 features are extracted. For filtered signal in figure 4, Features are extracted where the Feature Extraction Result containing 150 features is shown table 1.
Plot of Feature Extraction parameters such as minimum in figure 7, average in figure 7, maximum in figure 8, standard deviation in Fig. 9 and variance in Fig. 10.

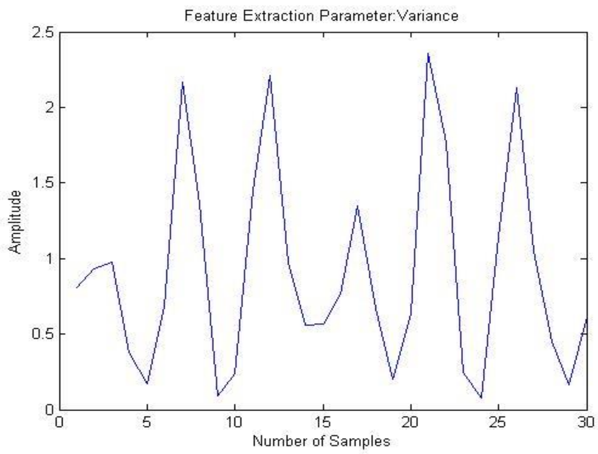

Fig. 10. Feature Extraction Parameter: Variance

VII. CONCLUSION

EEG signal is generated by phase-resetting method, using the inputs frame, epochs, sampling-rate and position.The experimental events reset the phase of ongoing oscillations in the range 4-16Hz.The generated EEG signal is shown in figure 3. EEG signal is pre-processed using Savizky-Golay Filter;signal is smoothened based on local least-quares polynomial approximation. The effect of noise on original signal is reduced. Filtered signal is shown in figure 4, and their comparison in figure 5.The Features are extracted based on the Mathematical calculations like Average, Maximum, Minimum, Standard Deviation and Variance methods. The plot of Feature Extraction parameters as shown in figures 6, 7, 8, 9 and 10.Total 150 features are extracted and stored in table 1.

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Feature Extracted Result					
No. of Signals	**Minimum**	**Average**	**Maximum**	**Std Dev**	**Variance**
1	-0.50866	1.098614	2.516638	0.900551	0.810991
2	-1.89255	-0.88416	1.357794	0.963812	0.928935
3	-0.77844	0.453169	2.101164	0.988866	0.977856
4	-1.14132	-0.33252	0.64419	0.612614	0.375296
5	0.202152	0.639003	1.364992	0.412028	0.169767
6	-1.65681	-0.79449	0.97369	0.826637	0.683328
7	-1.63437	0.413766	2.178944	1.471515	2.165356
8	-1.71322	0.098979	1.267396	1.16866	1.365767
9	-0.37771	-0.15568	0.547949	0.299562	0.089737
10	-0.77343	-0.13064	0.783387	0.48412	0.234372
11	-2.10949	0.12997	1.052314	1.204202	1.450103
12	-1.9713	0.333348	2.320654	1.487511	2.212689
13	-1.38273	-0.70431	1.633515	0.988572	0.977275
14	-0.53169	0.537984	1.729964	0.747066	0.558108
15	-0.91427	0.189546	1.358599	0.750281	0.562922
16	-0.89754	0.96839	1.998508	0.873106	0.762314
17	-2.44983	-0.54522	0.695451	1.159814	1.345168
18	-0.89211	0.378334	1.361148	0.81848	0.669909
19	-1.36673	-0.65667	-0.06902	0.450084	0.202576
20	-0.50294	0.824137	2.051507	0.801527	0.642445
21	-2.53607	-0.45966	1.255343	1.535916	2.359039
22	-1.61409	-0.07071	1.75398	1.328482	1.764865
23	-0.42472	0.160552	0.854498	0.491732	0.241801
24	-0.33022	0.123965	0.497578	0.27978	0.078277
25	-1.23113	-0.15631	1.646502	1.069009	1.142779
26	-1.98372	-0.28527	1.744887	1.459619	2.130487
27	-1.47315	0.672297	1.564352	1.024889	1.050398
28	-1.49974	-0.52773	0.336958	0.669129	0.447733
29	-0.45591	0.152124	0.678548	0.406766	0.165459
30	-0.82654	-0.14637	1.131242	0.786705	0.618905

Table1. Feature extracted result

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