Sleep Disorder Classifiers Using EEG Signal Processing

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Abstract— Any change in sleep pattern which negatively affects the health is termed as sleep disorder. This paper aims to detect different types of sleep disorders and analyze the performance of the classifiers namely neural networks, ANFIS and SVM. Sample EEG signals are taken from CAP SLEEP DATABASE. For each signal, the information from at least 3 EEG channels (F3 or F4, C3 or C4, O1 or O2) is tabulated. EEG signals consists of different frequency bands namely, alpha (8-12 Hz) and beta (14-32 Hz) theta (4-8 Hz). A band pass filter is designed to extract alpha band from the EEG dataset and average power spectral density of this band is computed using Welch method. Statistical parameters like mean, standard deviation of sample data and obtained PSD of alpha wave are fed as input to the different classifier. A FIS model using grid partitioning method is generated. System was trained for 80 samples using hybrid algorithm for 25epochs in 2 seconds and the training error was 0.66257.20 samples were used to test the classifier and the results shows an average testing error of 0.50924 and an accuracy of about 91%. The SVM testing gave an accuracy of 92%.

The disorders identified and classified in this paper are bruxism, narcolepsy, insomnia and nocturnal frontal lobe epilepsy. The data is read as '1' for bruxism '2' for epilepsy, '3' for no sleep disorder, '4' for insomnia and '5' for narcolepsy.

Index Terms— EEG, ANFIS, SVM, FIS, PSD

I. INTRODUCTION

Getting a sound sleep is vital for health. Sleep disorders can be defined as changes in sleeping patterns or habits that can negatively affect health. [1] Disordered sleep can be categorized into insomnia, narcolepsy, Parasomnias, Bruxism and circadian rhythms sleep disorders etc. Insomnia is very common among depressed patients. This includes difficulty in staying asleep (sleep maintenance insomnia) and difficulty in falling asleep (sleep onset insomnia). Parasomnias, a category of sleep disorders, are often associated with disruptions in slow wave sleep. Bruxism is a condition in which you grind, gnash or clench your teeth. Narcolepsy is a chronic neurological disorder caused by the brain's inability to regulate sleep-wake cycles normally.

One in 2000 individuals are getting affected by a neurological disorder known as Narcolepsy. Even after having an adequate amount of sleep during night the affected ones feels like falling asleep during day time. They are also characterized by sudden brief spells of muscle weakness termed as cataplexy. Others are hypnagogic (occurring at the onset of sleep) or hypnopompic (occurring at the end of sleep) hallucinations, sleep paralysis and automatic behavior. The study of narcolepsy has revealed some basic information about sleep. It has shown that wakefulness and sleep are not mutually exclusive states, and that one state can intrude into another, often resulting in striking consequences.

Insomnia[2] is the most prevalent sleep complaint in general population. It can be described as the inability to obtain sleep that is long enough to give a feeling of being rested or refreshed the following day. Although some insomnia may be constitutional in nature, there is evidence that untreated insomnia is a risk factor for the development of psychiatric problems, such as depression or substance abuse. There is convincing evidence to show that the depression may cause insomnia, and insomnia may cause depression. Insomniacs experience an overall increase in arousal and cortisol secretion. Although numerous pharmacological treatments are available, the benzodiazepines and the newer, non-benzodiazepines are the two classes of medication approved for the treatment of insomnia.

NFLE stands for Nocturnal frontal lobe epilepsy. w nocturnal resembles something that happens at night, frontal refers to front part, lobe meaning a fairly round flat part of ear, and epilepsy referring to a prolonged disorder in which a person suffers from regular seizures .A person affected by epilepsy suffers from seizures during sleep which arises from frontal lobe. Mild seizures make the feeling of waking up during sleep. Regular sudden movements like bicycle riding are all part of this disorder. Roaming around like sleep walking, singing songs and producing different voices are all seen in this patients. Some may have simple incidents that can include regular, sudden movements like bicycling movement of legs and motions of the arms.This disease can be misunderstood as night terrors or night mares.

Bruxism is the medical term for grinding the teeth and clenching the jaw. People sometimes grind their teeth without it causing any symptoms or problems. But regular, persistent teeth grinding can cause jaw pain and discomfort and wear down your teeth. It can also cause headaches and earache. Most cases of teeth grinding (nearly 80%) occur subconsciously during sleep. It's usually associated with contributing factors, such as stress or anxiety. Bruxism also affects people when they're awake, although this is more likely to be clenching the teeth and jaw, rather than grinding their teeth. Most people do it subconsciously while concentrating or when they're in stressful situations. Many people with bruxism find it will come and go. It's likely to be worse during stressful periods.

II. CLASSIFIER NETWORK FOR SLEEP DISORDER

Sleep disorders[3][4] can lead to depression and in worst cases it can lead to suicide. [5]Hence prediction of sleep disorders is important. Proper medication and control is mainly important. Classifiers helps in identifying the type of disorder . these classifiers can be trained to predict any real time event. Machine learning classifiers are gaining popularity in real time applications. This work aims in developing a system based on three classifiers in order to identify presence of sleep disorders and categorize the same. Performance and accuracy of three classifiers namely Neural networks, ANFIS and SVM are analyzed using the same application. The features required for the classification are extracted using MATLAB code and respective tool boxes are used for the classification.

The systems can be organized as follows:

- Extracting different frequency bands of an EEG signals eliminating the noise signals.
- Computation of PSD using Welch method for the extracted bands.
- Preparing the training data and testing data with selected features namely
- Testing the classifier with test data.

III. METHODOLOGY

The interconnection of blocks shown in fig. 1 forms the sleep disorders classifier. The input datasets are taken from publicly available database physionet.org/physiobank/database [1]and the processed to obtain the statistical parameters that can be fed into the classifier to obtain the desired results.

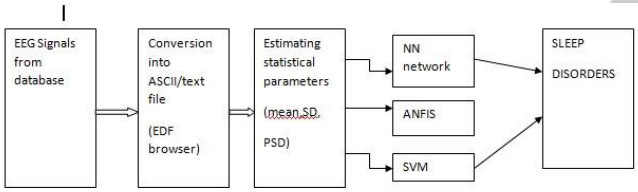

Fig.1 Block Diagram of the Classifier.

PhysioBank contains collection of EEG records and sleep related data in EDF format. They own collection of different biomedical signals intended for research and projects. The database also holds the records details. Once the data is downloaded from database it has to be converted into text format. EDF browser is a tool which coverts EDF files to ASCII /text files. It is an open source tool with many functions. Once the data is converted into text file, the next is to estimate statistical parameters. The statistical parameters are chosen in accordance with the nature of EEG signals. The classification is based on the amount of time during which the EEG is stationary which ranges from several seconds to several minutes .Hence to analyse EEG sleep data mean, SD and power spectral density is chosen as the features.

Neural networks are information processing network interconnected by large number of processing elements known as neurons to solve specific problems. Classification of data and pattern recognition problems are solved using a learning process. These are efficient networks that can detect trends and extract patterns from precise data better than human and computer techniques. Firing rules are the basic building blocks of neural networks. Pattern recognition problems are solved using feed forward networks. It learns from the input patterns and produces a output pattern which is least different from the input patterns. A back propagation algorithm further reduces the error in matching the inputs with the output.

Another type of classifier called ANFIS based on neural networks and Takagi–Sugeno fuzzy inference system. These are used for data modeling and networks uses IF THEN rules are used to extract the conclusion by testing different conditions. Fuzzification, Aggregation, Activation, Accumulation, Defuzzification are the steps involved in classifying the data.

A supervised learning approach is done by one different type of classifier called SVM (support vector machine). Classification and regression challenges are met using this classifiers.

The features thus extracted are used in preparing the data set. Classification of the data is carried out in two steps namely training and testing. Separate set of samples are used for training and testing. The dataset with the features are fed into the classifier network consisting of three type of classifier. Performance analysis of these networks for a multi class problem is found out at the end of the testing phase. Classification is carried out in two steps:

Training

The statistical parameters which define the dataset are loaded into the three classifiers. Neural networks trains the network using back propagation method. ANFIS creates a FIS model using the neuro adaptive fuzzy interference system. The desired output is loaded along the training data set. The classifiers learn from the data and adjust the parameters accordingly. ANFIS uses grid portioning algorithm to train the network. The type and number of membership function should be chosen according to the nature of the training data.SVM are another class of learning algorithm which uses different Kernels to classify the data. The type of kernel must be chosen according to the data. Different membership functions and kernels will have different effects on data.

Testing

The classifiers are tested using a test set. Neural networks separate the data into training, testing and validation. The pattern recognition tool box plots the ROC curve and confusion matrix from the set of data. The performance can be evaluated from these two curves. ANFIS plots the training data versus testing data and hence average testing error can be noted. SVM specifies the accuracy percent once the testing is completed.

IV. PERFORMANCE ANALYSIS OF CLASSIFIERS

Extraction of EEG bands and power spectral density

Different bands are extracted using band pass filters the band pass filters are designed using FDA tool box in MATLAB. Discrete wavelet packet transform is another efficient method of obtaining the EEG bands. Mean and SD are obtained using MATLAB functions. Power spectral density of extracted alpha wave is obtained using Welch method. Average PSD of alpha wave is another feature which characterizes the data set. Table 1 shows sample list of computed values for records taken from the database.

Table 1. Statistical parameters of EEG samples

Disorder	PSD of alpha wave	Mean	SD
Bruxism	9.9397e-06	1.1364	7.2157
Bruxism	4.8739e-05	2.9066	9.1793
Insomnia	4.8320e-05	0.0221	4.1869
Insomnia	7.8920e-05	1.2840	9.275
Insomnia	3.665e-05	-3.0313	27.3195
No sleep disorder	8.5083e-05	1.0535	7.1300
No sleep disorder	5.057e-05	1.6658	4.3051
No sleep disorder	1.2952e-04	-6.2856	7.4594
No sleep disorder	5.7135e-05	3.8772	4.9392
No sleep disorder	3.2209e-05	1.2496	7.1373
No sleep disorder	0.0011	1.4261	34.1799
No sleep disorder	2.0678e-04	14.9002	8.9822
No sleep disorder	7.3980e-08	0.6807	0.3881
No sleep disorder	3.805e-11	0.0163	0.0246
No sleep disorder	8.321e-07	1.8808	0.2574
Narcolepsy	3.6960e-04	53.787	37.4633
Narcolepsy	1.3170e-04	22.1106	25.0224
Narcolepsy	0.0046000	38.6255	312.7110
Narcolepsy	3.6960e-04	53.7387	37.4633

A) NEURAL NETWORK CLASSIFICATION RESULTS

1. Choose nprtool from matlab
2. Load train data and test data from the workspace
3. Plot the ROC and confusion matrix

Following figures shows the results

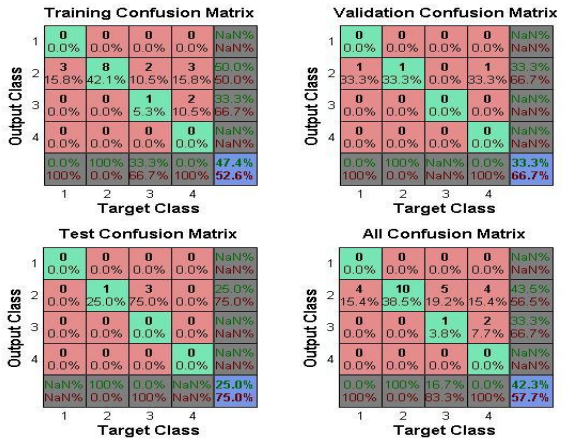

Fig.2 On the confusion matrix plot, the rows correspond to thepredicted class (Output Class), and the columns show the true class (Target Class). The diagonal cells show for how many (and what percentage) of the examples the trained network correctly estimates the classes of observations. That is, it shows what percentage of the true and predicted classes match. The off diagonal cells show where the classifier has made mistakes. The column on the far right of the plot shows the accuracy for each predicted class, while the row at the bottom of the plot shows the accuracy for each true class. The cell in the bottom right of the plot shows the overall accuracy

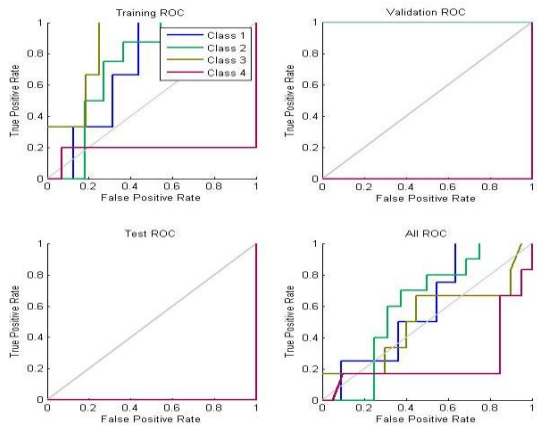

Fig.3 **ROC curve :** plots the receiver operating characteristics for each class. The more each curve hugs the left and top edges of the plot, better the classification.

B) **ANFIS CLASSIFIER RESULTS**

1) Load the training data
2) Create the FIS model
3) Specify the membership functions
4) LSoad the test data

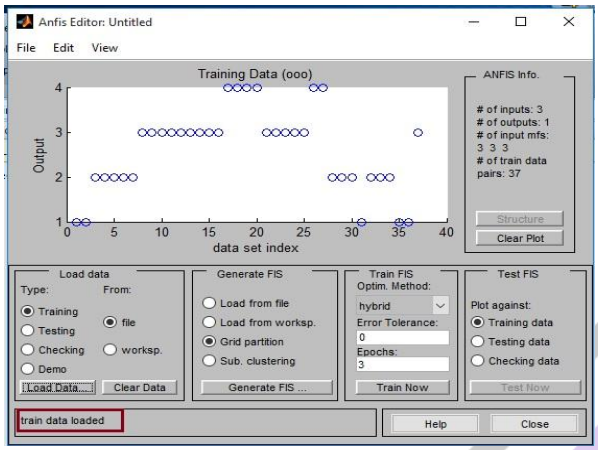

Fig.5 **ANFIS load train data :**training samples categorised into four class of disorders is loaded from workspace

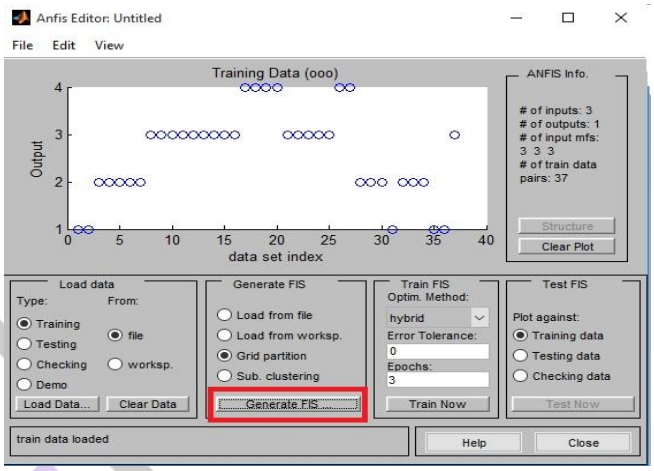

Fig.6 **Generate FIS:**FIS model can be created by selecting the method grid partitioning followed by Generate FIS command

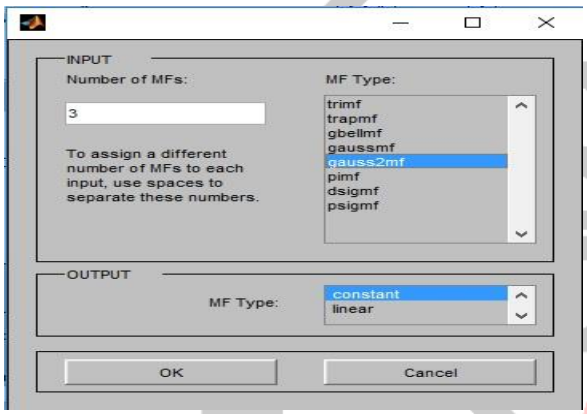

Fig.7 **FIS membership function:** defines the dataset. For our classifier mean, SD, PSD are the functions hence we choose 3 as number of MFs and type as gauss2mf because it performs well for statistical analysis

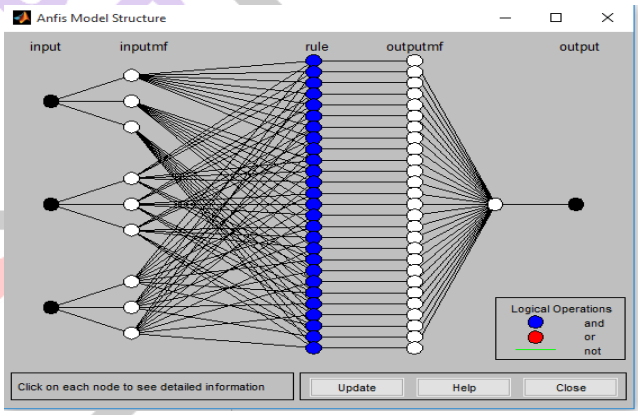

Fig.8 **FIS model:** generated FIS model can be viewed from structure option from the ANFIS editor

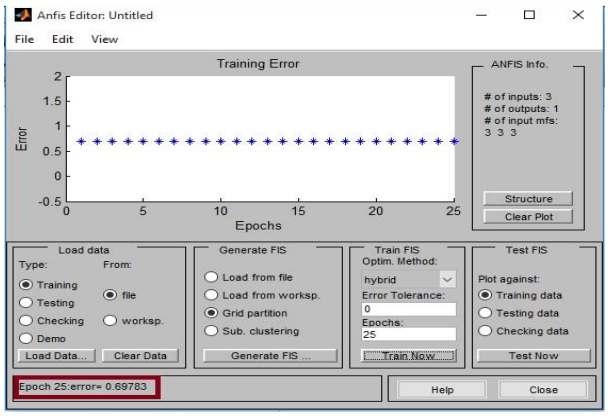

Fig.9 **ANFIS training error:** indicates the training status and once training finishes at specified number of epochs training error is noted. the error can be reduced by using more number of samples for training.

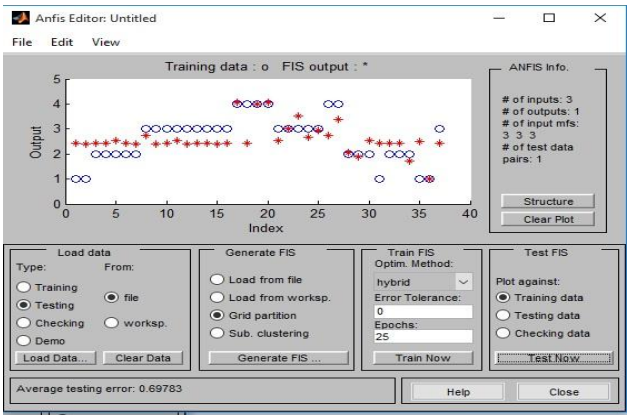

Fig.10 **ANFIS test data :** The test data loaded from workspace is plotted against the training data

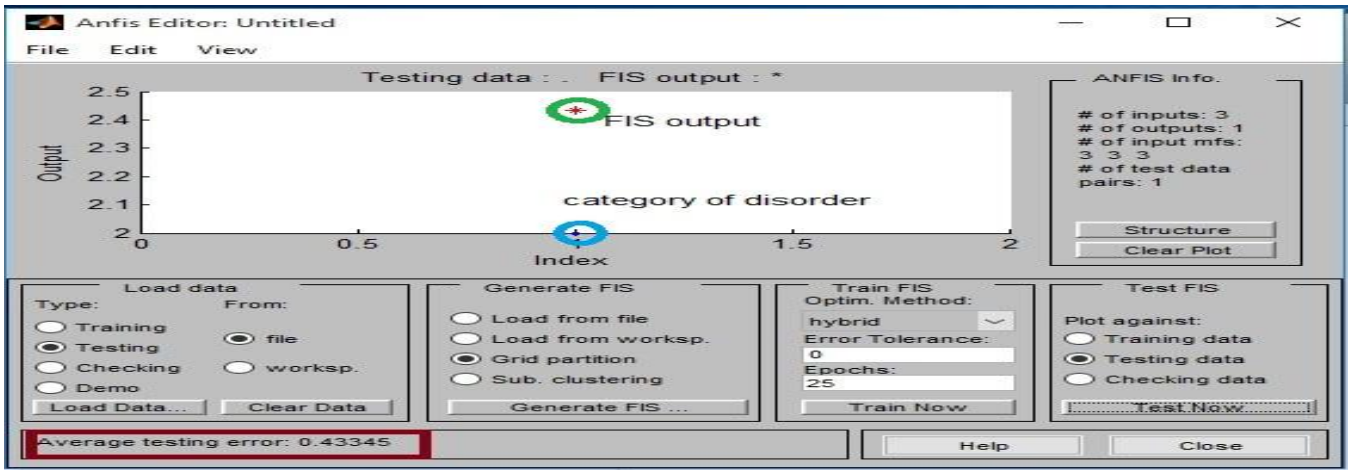

Fig.11 **FIS output :** The window indicates both category of classification as well as the classified output. Also testing error indicated can be noted. The testing error can be reduced by using different algorithms and increasing the number of samples used for training.

C) SVM CLASSIFIER RESULTS

1) Run SVM matlab code
2) Load train data
3) Load test data

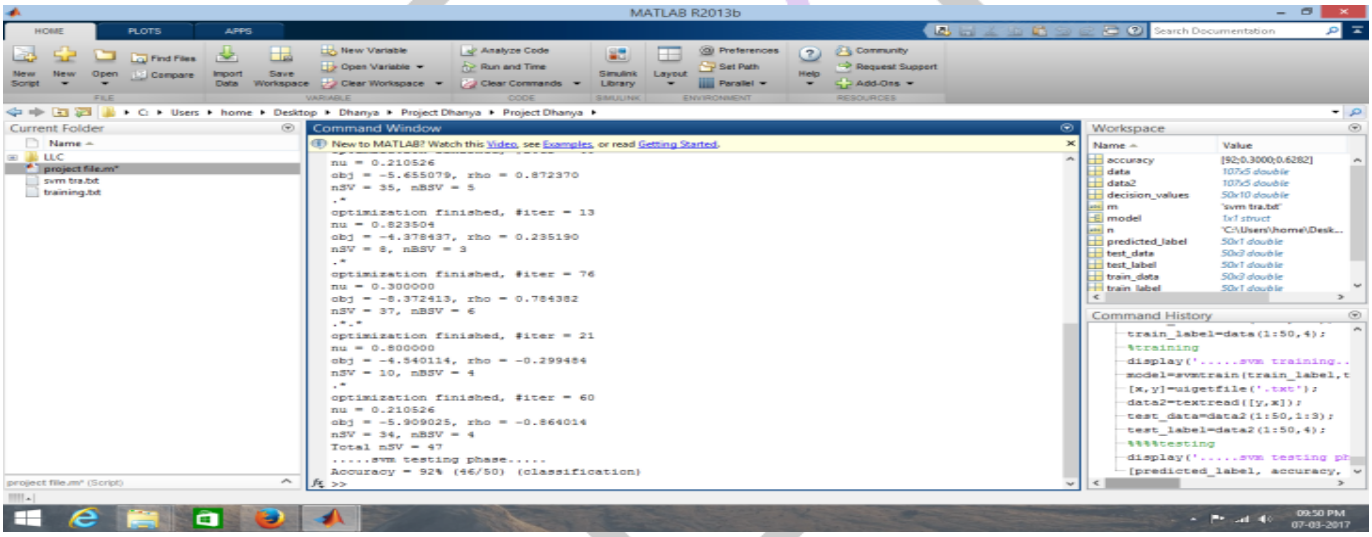

Fig.12 SVM classifier results: The same data can be trained using different kernels and different labels. Accuracy can be further increased using sample selection algorithm. SVM proves to be one if the efficient classifiers.

V. RESULTS AND DISCUSSIONS

The parameters a of the classifier namely training error, testing error, accuracy can be taken into consideration to evaluate the performance of the three classifiers. The tabulation (Table 2) shows the different parameters of the classifier.

Table 2. Performance analysis of the classifier

Classifier	Training error	Number of epochs	Accuracy
NPRTOOL	0.9526	900-1000	86%
ANFIS	0.6625	20	91%
SVM	0.8	32	92%

As seen from Table the learning duration of ANFIS is very short than neural network case. It implies that ANFIS reaches to the target faster than neural network. When a more sophisticated system with a huge data is imagined, the use of ANFIS instead of neural network would be more useful to overcome faster the complexity of the problem. In training of the data, ANFIS gives results with the minimum total error compared to other methods. This shows that the best learning method is ANFIS among the others. However, when the trained parameters were applied to checking data, total error of neural network is smaller than that of ANFIS. Although it looks like a contradiction, the reason of this situation is due to the amount of short data, which is not enough to good learning.

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