Display Control Using EOG Signals

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***Abstract*: With development of technology, demand for the screen devices has also increased. In this paper, control of a screen of the device through the EOG signals is discussed. The general idea is to collect the EOG signal from the user and classify them to neutral, left, right, up, down and blink. Based on the decision of classifier, the cursor of the screen moves in that direction and depending the blinks interval of time, the brightness of the screen is controlled.**

***Index Terms*: EOG, Feature Extraction, Kernels, K-Nearest Neighbor Support Vector Machine.**

I. INTRODUCTION

Electrooculogram (EOG) signal is measurement of the cornea-retinal standing potential that exists between the front and the back of the human eye. The main idea is to develop an interface using the EOG signals which helps users have better experience. Since EOG signals have significant information as the person's eye movement and visual fatigue, these signals can be used to control the screen of the system. These signals are processing in such way that the information required is used and the noise in the signals is rejected. In our project, we will noise removal filter, baseline removal technique as the pre-processing technique. Further the features of these pre-processed signals are extracted, where statistical features are preferred. There will be two classification techniques: Support Vector Machine and K-Nearest Neighbour. These classification techniques are implemented separately on the signals and respective results may be recorded. MATLAB environment is used for processing signal and further coding.

The paper is divided into four sections. Section II describes the problem statement. Section III is the literature review of the methods used: *Pre-processing, Learning.* Section IV describes these methods in detail and how we tackled the problem. Finally, section V presents the expected results we are interested in.

II. PROBLEM STATEMENT

With the development in technology, electronic screens have become major part of day to day life. To make the technology more accessible for the physically challenged, development of human-computer interface using EOG is important. In this project, EOG signals are used to move the cursor to neutral, left, right, up and down. As the person tends to be in front of screen for long time duration, visual fatigue increases. In this situation can be controlled by increasing and decreasing the brightness of the screen to reduce strain on eye. The process of the data acquisition and processing is as follows:

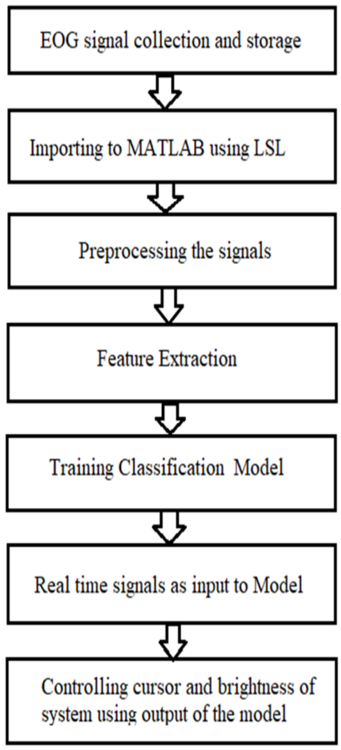

Fig. 1. Flow chart for the basic design.

EOG signals are recorded using the Bio-Radio 150 from the user. The data is recorded using the Lab Stream Layer and Lab Recorder. The data collected is then processed using MATLAB. Prior to feature extraction, the signal is passed through filters for noise reduction and better information reduction. After this, the statistical features are extracted from the signal, features are then fed to decision making algorithm that is SVM (Support Vector Machine) and KNN (K- Nearest Neighbour) algorithms separately. The vertical and horizonal signal collected from user are used to control the cursor and then blinks are used to detect the visual fatigue and control the brightness.

III. LITERATURE REVIEW

A. *Pre-processing:*

Pre-processing is an essential task performed after data acquisition which involves in the removal of unwanted noise or high frequency data present in the signal obtained. EOG signal is generally contaminated with artifacts like head movements and eyebrows movement which are needed to be removed. It can be easy to eliminate noise or high frequency noise but in order to eliminate the artifacts the data needs to be studied, the difference must be observed, and the necessary step must be taken to remove it. Reza has used a technique which helps in recognition of eye artifacts by analysing the system dynamics of eye [1]. But Aungsakul has a simpler way to detect these artifacts, where she performed the same experiment five times and compared them which helped to identify the artifacts [2].

Feature extraction is a dimensionality reduction process where data is reduced into groups or features which can be processed and classified easily to achieve higher accuracy. There are many papers exploring different techniques and different tools to select different features to achieve stable model and high accuracy. Reza has used a MIToolbox , which can be an efficient method for selecting features called Class Separability Feature Selection based on the channels [1]. Where as Sirvan has used simple features based on his data i.e. by observing and trial and error where he observed that Large number of high dimensional features can make the classification process, more complex and less reliable due to redundancy [3], he also tabulated the comparison of different features he used. Wrapper algorithms are feature subset algorithms which are used to select feature based on the performance of classifier. Mala used minimal redundancy maximal relevance (mRMR) algorithm i.e. a sequential forward selection algorithm which uses information to analyse relevance and redundancy and selects based on correlation with classifier [4].

B. *Learning*

1) *Support Vector Machines:*

The support vector machine is a supervised learning algorithm which divides that data into two classes. SVM creates hyperplane with the help of support vectors which are equidistant from the hyperplane. Optimal hyperplane means a linear decision surface that splits n-dimensional space into two parts and simultaneously the distance of decision boundary from the data of both classes should be as far away as possible [5].

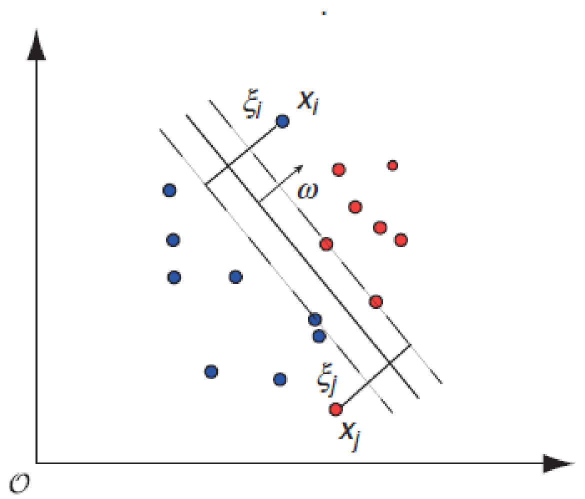

Fig 2: Classification the data set using Linear SVM

The above Fig 2 [6] shows the linear hyperplane which at distance of w from support vectors of each class. Kernels play major role in the classification of data. Linear kernel predicts that class of the next input data using the previous coefficients of the estimated model. Using kernel, the data is transformed such that transformed data can be linearly separated. Commonly used kernel functions are

Polynomial kernel function:

$$K(\mathrm{x},\mathrm{y}) = (x^T\mathrm{y} + \mathrm{c}\,)^d$$

where x is features of data, y output data, c is the cost function (tradeoff cost) and d is the degree of the polynomial.

Gaussian kernel function:

$$K(\mathrm{x},\mathrm{y}) = exp\left(\frac{-|x-y|^2}{2*std}\right)^d$$

Where std is the parameter which is width of the Gaussian function. SVM has been mainly used for the classification of EOG Signals in many of the experiments conducted according paper [7] [8]. Using the statistical features has better results in SVM compared to the power spectral density. The performance of SVM is better and fast when the Statistical features are used in classification compared to Artificial Neutral Networks according paper [9] . The Multi-class SVM significant accuracy as ANN is not as accurate.

2) *K- Nearest Neighbour:*

kNN method is a lazy method or non-parametric and regarded as on the simplest method in machine learning [10]. kNN is a supervised learning algorithm where the result of new instance is classified based on the majority of K nearest neighbour’s category [11]. kNN classifies the data based on the distance and nearest neighbour. The distance measures the difference two instances. This distance is called Euclidean distance which can be shown as follows [11]

$$d(\,i_1, i_2) = \sqrt{\sum_{j=1}^{n}(a_{i_1 j} - a_{i_2 j})^2}$$

Setting a k value is very complicated and challenging process as the entire process is based on the value of k. Shichao mentioned that a suitable k should satisfy $k = \sqrt{n}$ for training datasets larger than sample size of 100 [10]. In general, if k is a fixed value so there are many papers which proposed a dynamic k value such that an optimal value of k is selected in the algorithm and further classification is done.

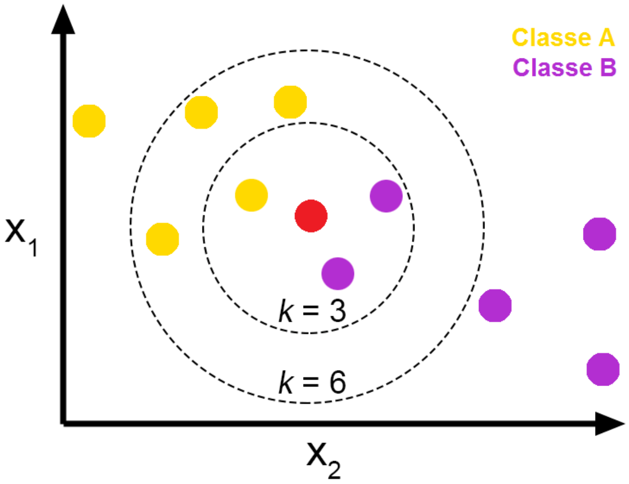

Fig 3: k-NN boundaries

For example, in the above figure k =3, then the comparing takes place between A and B i.e. yellow and purple dots respectively. For instance, if k=3 then the new instance introduced is taken into B class i.e. purple is taken has new instance. Another instance where k=6 then the new instance is taken a A i.e. yellow.

KNN classifier accuracy decreases with increase in the dimensions of data. Which can be eliminated by using efficient features or weighted features [12]. The major limitations of kNN are as follows

i. Better and efficient distance functions can be used for better attributes.
ii. Finding better K value for accurate results.
iii. Better estimation than simple voting.

With the combination of these three limitations Shweta has proposed a new enhanced algorithm for better accuracy [13].

IV. Proposed Method

The EOG signals are collected through the BioRadio 150 are processed in the MATLAB environment. The sampling frequency of the EOG signals is 480 Hz

A. *Pre-processing*

1) *Filtering*

Noise and artifacts are common part of the signals that collected. Power frequency noise, sensor noise and artifacts due to skin are some of major sources of the noise. The method employed to remove the unwanted parts of signal such as noise and artifacts is called filtering. As the data is collected, the first stage of data processing is filtering.

Butterworth Band stop filter is used to filter out the noise. The ground noise frequency is removed .59-61 Hz cut-off frequency is chosen for the filter and filter order is 4 [14].

2) *Feature Extraction:*

After data acquisition and filtering the next step is feature extraction which is dimensionality reduction or grouping of sample data as follows

i. Mean: Mean of the sample of EOG signal gives the average value of the set of samples. This is zero if the signal is in neutral position, positive or negative depending on the direction in which user is seeing.

$$Mean = \frac{1}{n}\sum_{i=1}^{n} x_i$$

ii. Minimum: The amplitude of EOG signal at lowest point (minimum negative value)

$$Minmum = \min{(x_i)}$$

iii. Maximum: This returns maximum peak amplitude of signal.

$$Maximum = \max(x_i)$$

iv. Area under the curve: This returns the area under the curve which varies each class.

v. First Quartile: Median in the first 25% of the signal is given

$$First\ Quartile = \frac{n}{4}$$

B. *Learning*

i. *Support Vector Machine*

Using standard data set, the framing and feature extraction is done as discussed in previous section. The model is trained using the data set using Gaussian SVM classifier. The accuracy is 804% .Standard data had only two classes left and right, confusion matrix of the trained model.

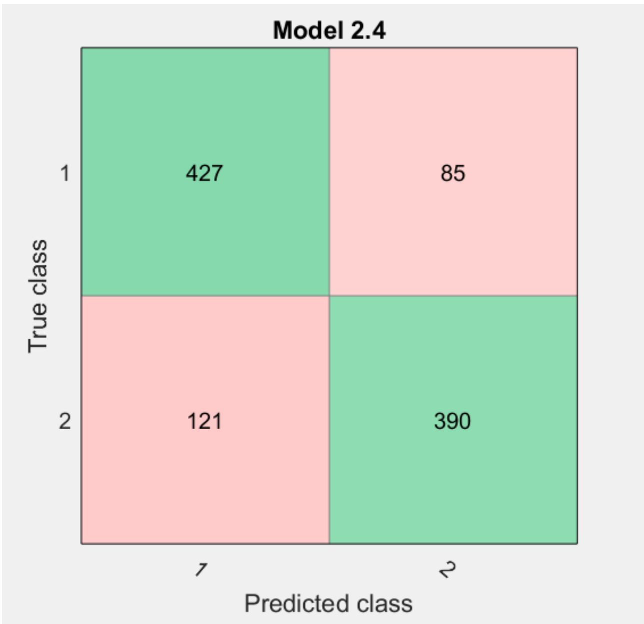

Fig 4: Confusion matrix of SVM Gaussian Kernel

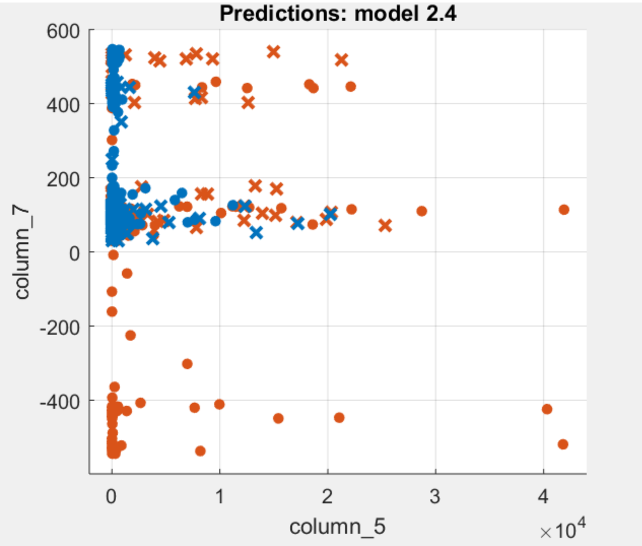

Fig 5: SVM Classification Model, Mode vs Variance

ii. K- Nearest Neighbour:

Same process of denoising and feature extraction are implemented. The model is trained using the data set using KNN classifier. The accuracy of the KNN model is 85% which is better compared to that of the SVM.

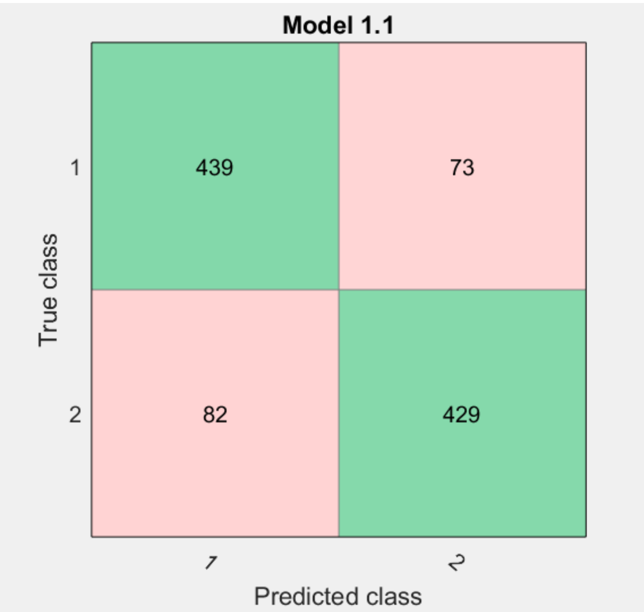

Fig 6: Confusion matrix for k-NN

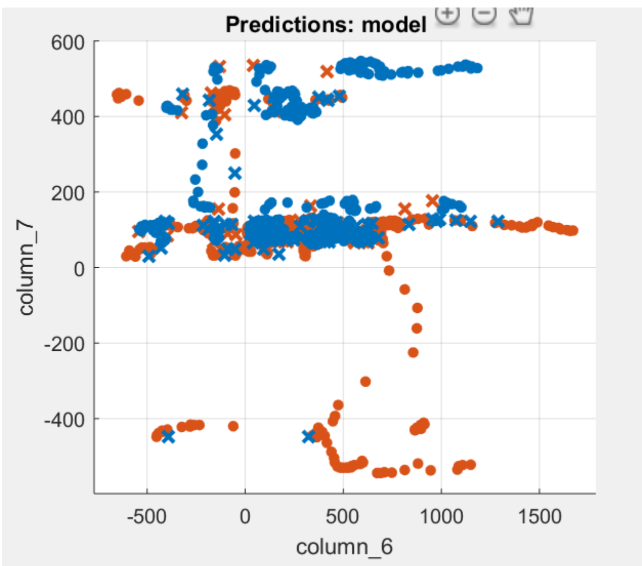

Fig 7: k-NN Classification Model, Mode vs Median

V. RESULTS

The EOG signals collected to classify using classification techniques. The notch filter design for removal of the noise and chateristics are shown below.

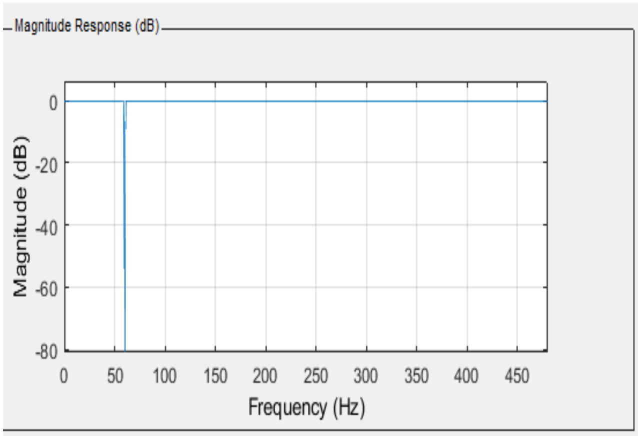

Fig 4: Magnitude response of notch filter

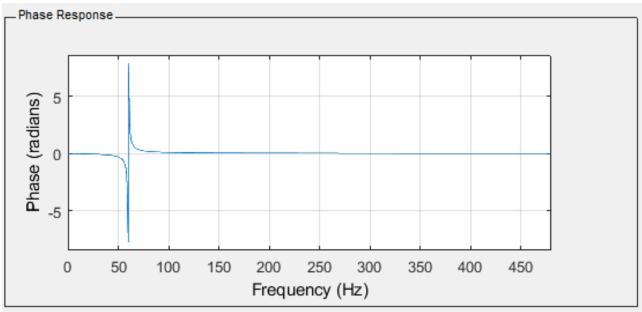

Fig 5: Phase response of notch filter

Both the figures show the change at 50 Hz frequency i.e. there is no signal from 59 Hz to 61 Hz as shown in fig 1 there is a dip in the frequency.

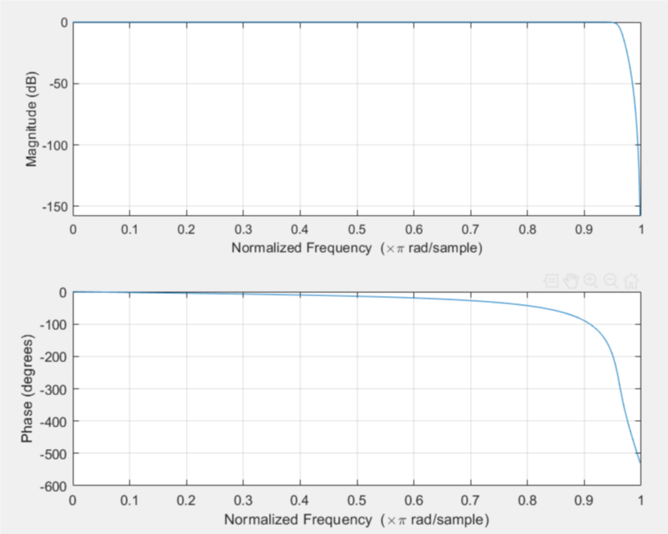

Fig 6: Magnitude and Phase response of low pass denoise filter

The raw EOG signal for the horizontal eye movement is shown below:

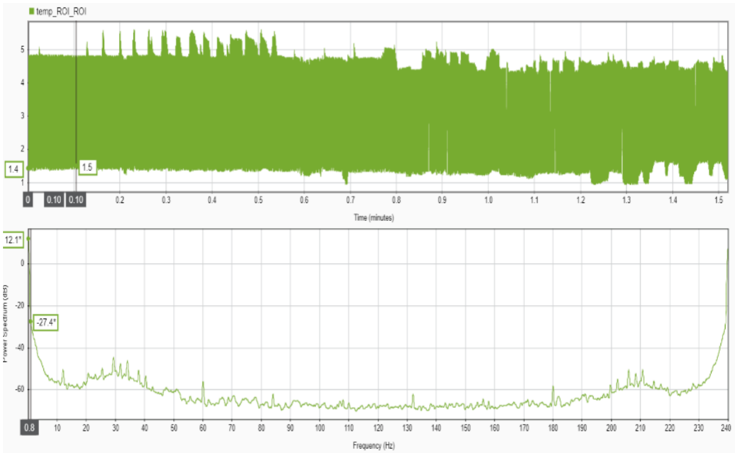

Fig. 7. Raw EOG signal

After filtering the raw data, the signals are shown below:

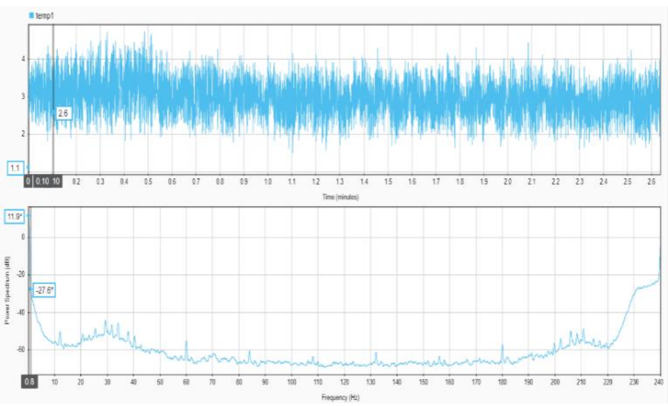

Fig. 8. Filtered EOG signal.

The complete EOG signal is then sampled into smaller groups as shown in the below figure.

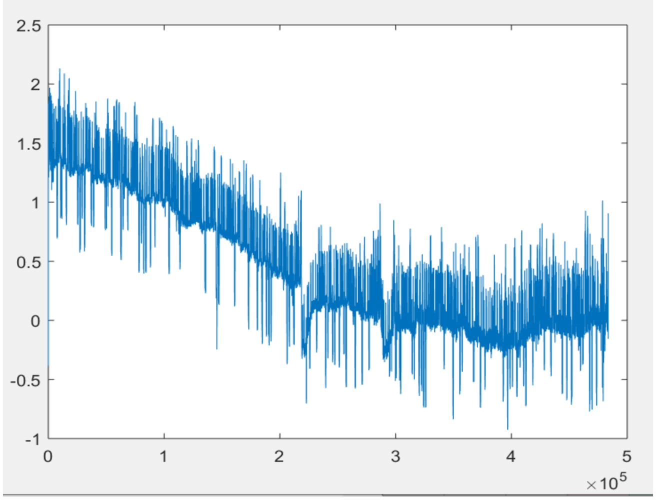

Fig. 9. Unfiltered and sampled EOG signal.

Sampled group of signals is further filtered and zero mean is done, and resultant signal is shown below.

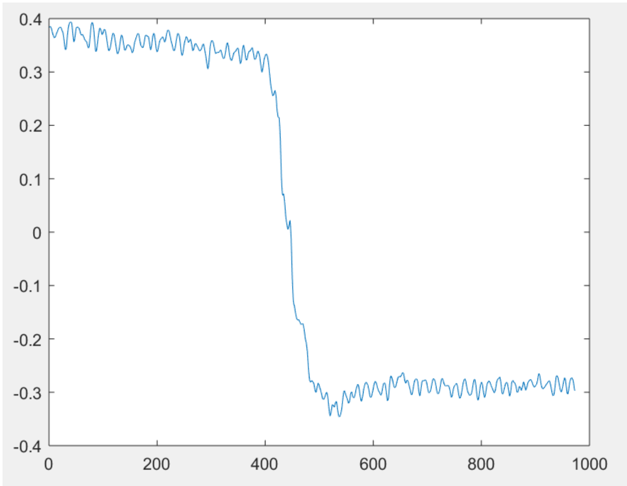

Fig. 10. Filtered and sampled EOG signal.

The sampled signal is then used for feature extraction and normalized, then the model is trained using SVM and k-NN classification methods. For training the model, the data from horizontal channel is used for classifying the signal into Up, Down, Blink, Neutral Class and Reject class as shown in Fig.15.

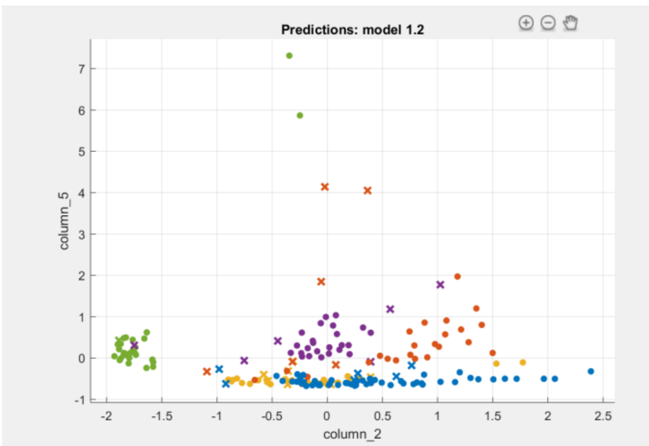

Fig. 11. SVM Quadratic Model

The SVM model with quadratic kernel is used for training and accuracy is 86.3%. The left and right classes are classified as reject class. Those rejected class, samples are further classified into left and right classes by using the second classifier which is linear SVM as shown below.

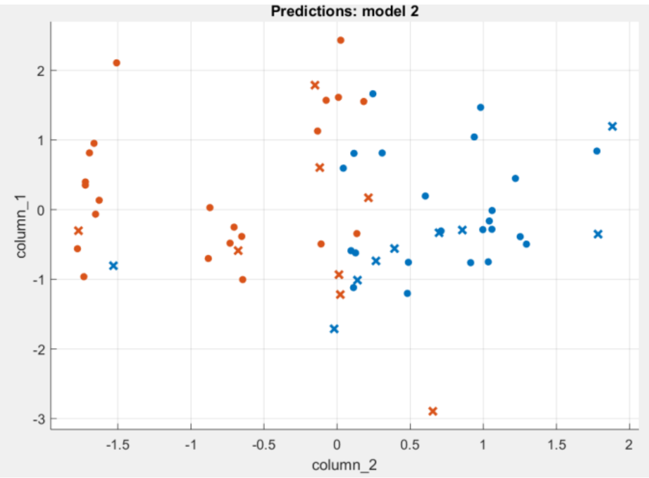

Fig. 12. Linear SVM Model

Test accuracy of the SVM model is 65.22% and the confusion matrix is as shown below in Table 1.

Table 1: Confusion Matrix of Test Data Classification

True Classes/ Predicted Classes						
Left	5	7	0	1	0	0
Right	0	0	0	0	0	0
Up	0	0	5	0	3	0
Down	2	0	1	7	0	0
Blink	0	0	2	0	5	0
Neutral	0	0	0	0	0	8

Similarly, the classification of the EOG signal is done using fine k-NN classifier as shown below and the accuracy of the training set is 78.6%.

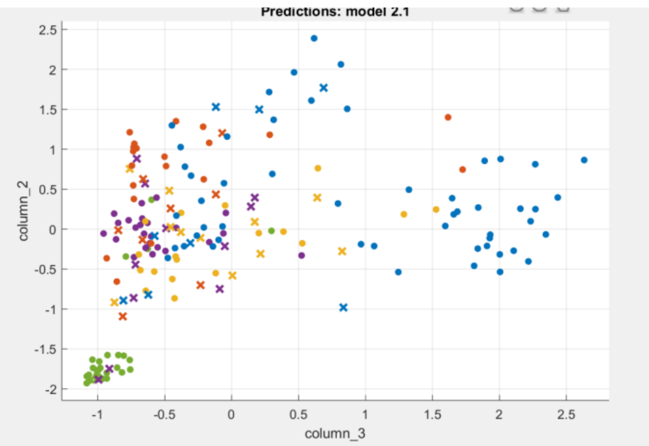

Fig. 14. Fine k-NN Model

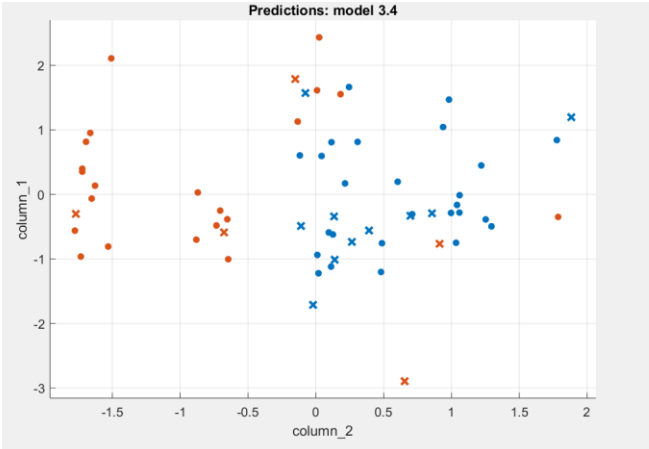

Fig. 15. k-NN cosine Model

The second classifier used to classify left and right classes is k-NN cosine classifier as shown above Fig.17.The test accuracy of the k-NN model is 71.74% and the confusion matrix of the test data classification is as shown below Table.

Table 2: Confusion Matrix for k-NN Classification

True Classes/ Predicted Classes						
Left	4	3	0	0	0	0
Right	1	4	0	1	0	0
Up	0	0	5	0	3	0
Down	2	0	1	7	0	0
Blink	0	0	2	0	5	0
Neutral	0	0	0	0	0	8

Depending on the output of the classifier the cursor control and brightness control of the screen is done.

Table 3: Comparison of Accuracy with State of Art Models

Accuracy	Eye Movement Pattern
70-95% [7]	Blink (various subjects)
65-70% [13]	Left, right, up, down
96-98% [14]	Double blink, left, right
62.5%-71.74% (our paper)	Left, right, up, down, neutral, blink

VI. CONCLUSION

This paper about classification of the eye movements using the EOG signal. With help of denoising filter and feature extraction, the characteristics of the signals are obtained. SVM and k-NN classification methods are used for classification of the signals. The test accuracy results are near by to few of the state of art model. Cursor movement is done using the output of the classifier which can be used to development applications.

VII. FUTURE SCOPE

The classification results can be improved by training the model with signals from different subjects and different environments. By using single classifier with probability of the classification can be made better.

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