Automation of Emotion Quadrant Identification by Using Second Order Difference Plots and Support Vector Machines

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EEG can reveal the real internal emotion of the subject, as it is a non-invasive way of capturing the brain waves and can't be affected by pretension or denial. This has made EEG a reliable source for research on emotion in current times, as it cannot be disguised. It captures the brain activations, mapping the brain states representing different emotional states directly [1]. Emotion recognition from EEG signals is a very cost-effective method to monitor the general wellbeing of individuals, employees of an organization or to cater to patients of mental health. Such a dataset is DEAP - Database for Emotion Analysis using Physiological signals, which is available online for academic research purposes [2]. In DEAP emotional dataset, brain signals of 32 volunteers, captured as they viewed 40 music videos of 1-minute duration each, are categorized on the quadrant of valence, arousal, dominance and liking, which signifies how they are associated with different emotions. The overview of the dataset used for experimentation is as shown in Figure 1.

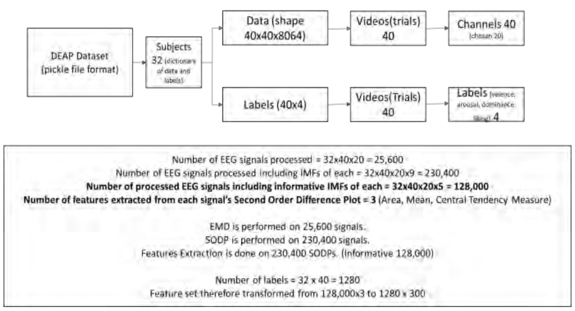

Figure 1: Overview of DEAP Dataset

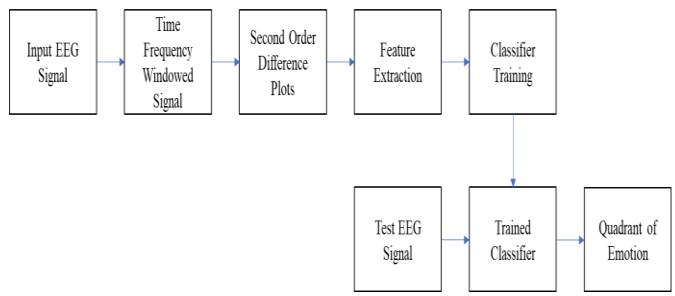

Figure 2: Complete Methodology

The authors have tried to extract relevant features to classify the emotions from the EEG signals by plotting of Second Order Difference Plots from windowed signal in time domain. Area of the elliptical region in these plots, mean and central tendency measure are the features considered and fed into the classifiers. Support Vector Machine is trained to perform binary and multiclass classification in different quadrants of valence, arousal, dominance and combinations of quadrants. The model is enhanced by hyper parameters tuning. Channel selection is done as per different brain regions. Methodology adopted to perform the research work is as shown in Figure 2.

Performance metrics from multiclass classifications were compared with that of multiple binary classifications. Statistical performances of the classifier have been evaluated by computing F1-Score and accuracy. The maximum accuracy of 88.12% was achieved for the classification of emotions in the quadrant of Low Dominance High Valence vs Rest.

The second order difference plot of resulting windowed signals is computed. This technique helps in the analytical study of correlation between consecutive rate values in a time series. [3] The second order difference plot of signal $x(t)$ can be obtained by plotting $X(t)$ against $Y(t)$ as in Figure 3.

$$X(t) = x(t+1) - x(t) \quad (1)$$

$$Y(t) = x(t+2) - x(t+1) \quad (2)$$

After pre-processing, the features extracted from the second order difference plot are Area, Mean and

Central Tendency Measure. Area calculates the area of the elliptic region of the second order difference plot. For a given radius r around the origin of the second order difference plot, central tendency measure is the ratio of the number of points within the radius, to the total number of points in plot. [4][5]

$$CTM(r) = \frac{[\sum_{i=1}^{n-2} \delta(d(i))]}{n-2} \quad (3)$$

where, $\delta(d(i))$ is 1 if

$$([x(i+2) - x(i+1)]^2 + [x(i+1) - x(i)]^2)^{0.5} < r \quad (4)$$

and otherwise $\delta(d(i))$ is 0.

Mean distance $D(\mathrm{r})$ is calculated by first evaluating the mean distance of each of the points d(i) lying within the circular radius r. [6]

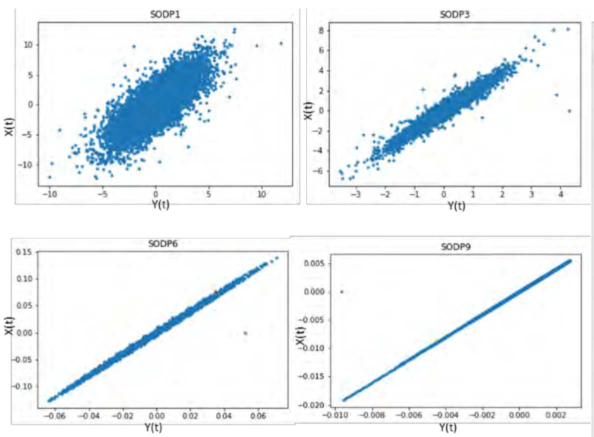

Figure 3: Second Order Difference Plots

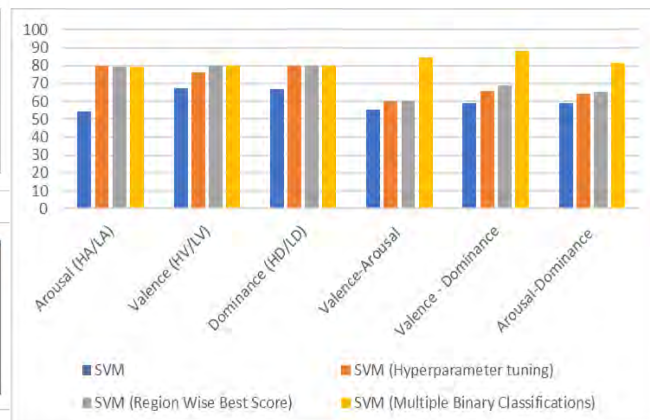

Figure 4: SVM Classifier Evaluation

Table 1. Accuracy for SVM Classifier Evaluation

Emotion/ Quadrant	SVM	SVM (Hyper Parameter Tuning)	SVM (Region Wise Best Score)	SVM (Multiple Binary Classifications)
Arousal (HA/LA)	54.5	80	79.12	79.12
Valence (HV/LV)	67.4	76	79.78	79.78
Dominance (HD/LD)	66.9	80	79.78	79.78
Valence-Arousal (HVHA/ HVLA/ LVHA/ LVLA)	55.3	60	60.76	84.69
Valence - Dominance (HVHD/ HVLD/ LVHD/ LVLD)	58.9	66	69.04	88.13
Arousal-Dominance (HAHD/ HALD/ LAHD/ LALD)	59.2	64	65.44	81.25

The results extracted from the methodology are presented in Table 1. SVM and hyper parameterized SVM has shown the variations in results in almost all the quadrants.

The combination of windowed signals along with SODP, from EEG data, gives significant results which have not yet been explored in emotion recognition research. Literature doesn't show considerable work in emotion recognition from EEG data in the quadrant of Dominance. In the quadrant of valence-dominance, we have achieved maximum accuracy of 88.13% and in arousal-dominance the max was 81.25%. SVM is the most commonly used classifier in emotion recognition through EEG signals, but the maximum noted accuracy is 86.28% by Zhang et. al. [7] in DEAP dataset. By proposed method accuracy obtained is 88.13%, in DEAP dataset, using SVM. An entirely automated python package was made through this project for data pre-processing, feature extraction, with available trained models for classification of emotion. Preprocessing of a single channel data was taking 7 mins earlier, which was improved to 3.2 mins by using optimized code and hyper parameters tuning. The scope for automatic emotion recognition systems is growing with availability of data and advancement of technology. General healthcare systems and regular employee metal health monitoring in organizations is becoming the norm. Such systems can help reduce the workload of professionals, and assist in monitoring the public mental health.

REFERENCES

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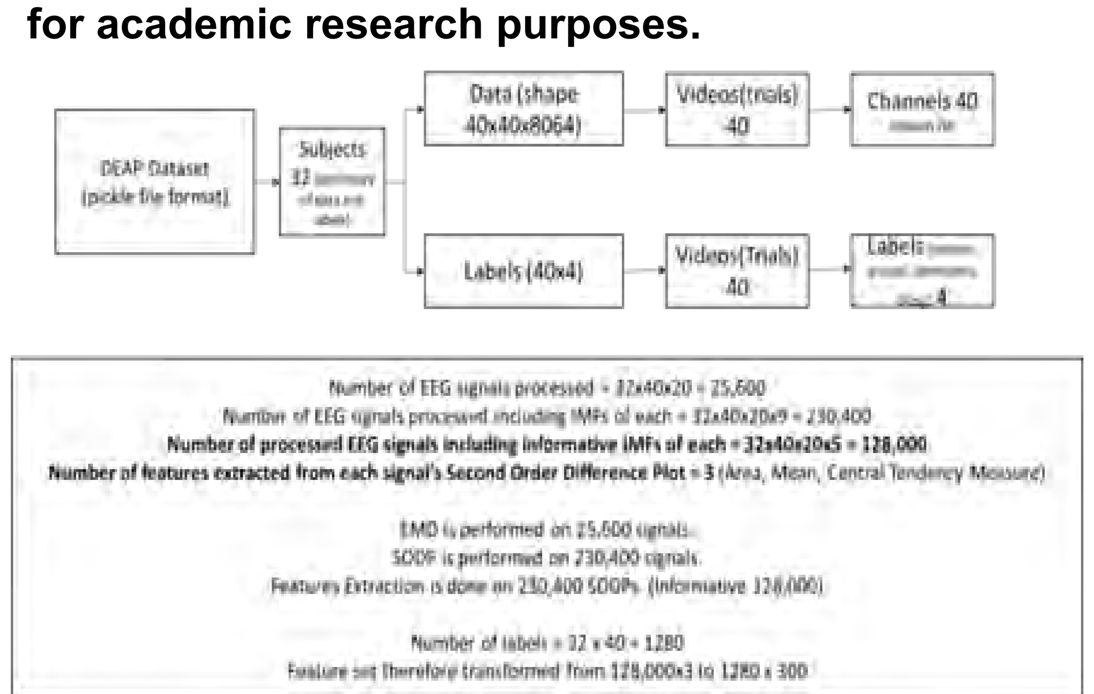
Abstract

- EEG can reveal the real internal emotion of the subject, as it is a non-invasive way of capturing the brain waves and can't be affected by pretension or denial.
- Emotion recognition from EEG signals is a very cost-effective method to monitor the general wellbeing of individuals, employees of an organization or to cater to patients of mental health.
- The authors have tried to extract relevant features to classify the emotions from the EEG signals by plotting of Second Order Difference Plots from windowed signal in time domain.
- Area of the elliptical region in these plots, mean and central tendency measure are the features considered and fed into the classifiers.
- Support Vector Machine is trained to perform binary and multiclass classification in different quadrants of valence, arousal, dominance and combinations of quadrants.
- The model is enhanced by hyper parameters tuning. Channel selection is done as per different brain regions.
- Performance metrics from multiclass classifications were compared with that of multiple binary classifications.
- Statistical performances of the classifier have been evaluated by computing F1-Score and accuracy.
- The maximum accuracy of 88.12% was achieved for the classification of emotions in the quadrant of Low Dominance High Valence vs Rest.

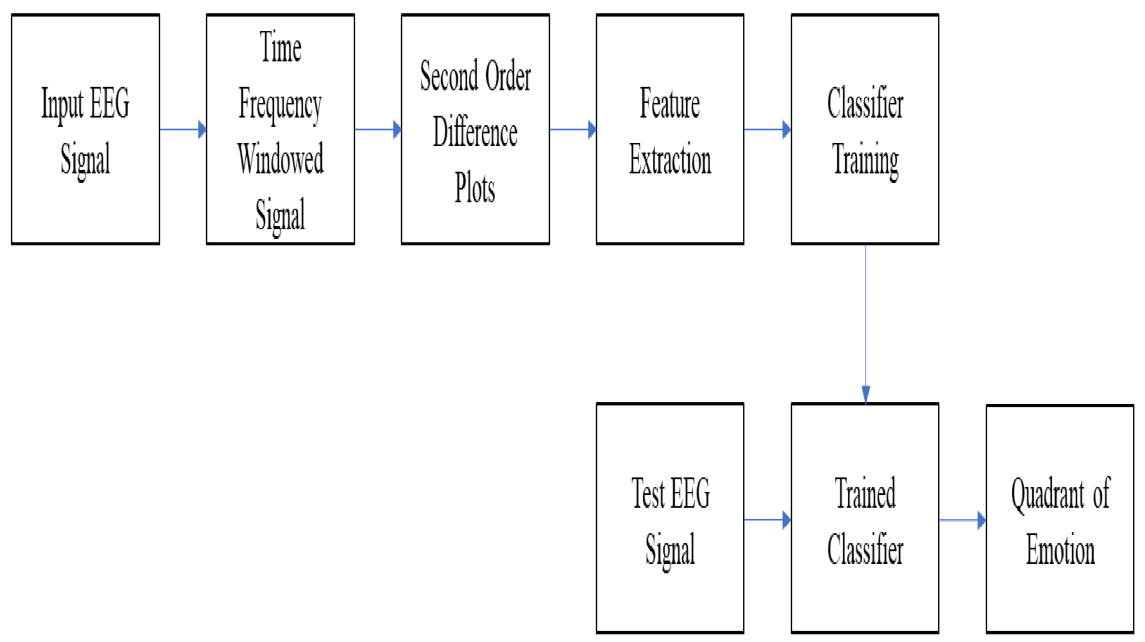
Overview of the DEAP Dataset

- DEAP - Database for Emotion Analysis using Physiological signals, is a dataset available online for academic research purposes.



- DEAP emotional dataset, brain signals of 32 volunteers, captured as they viewed 40 music videos of 1-minute duration each, are categorized on the quadrant of valence, arousal, dominance and liking, which signifies how they are associated with different emotions.

Complete Methodology

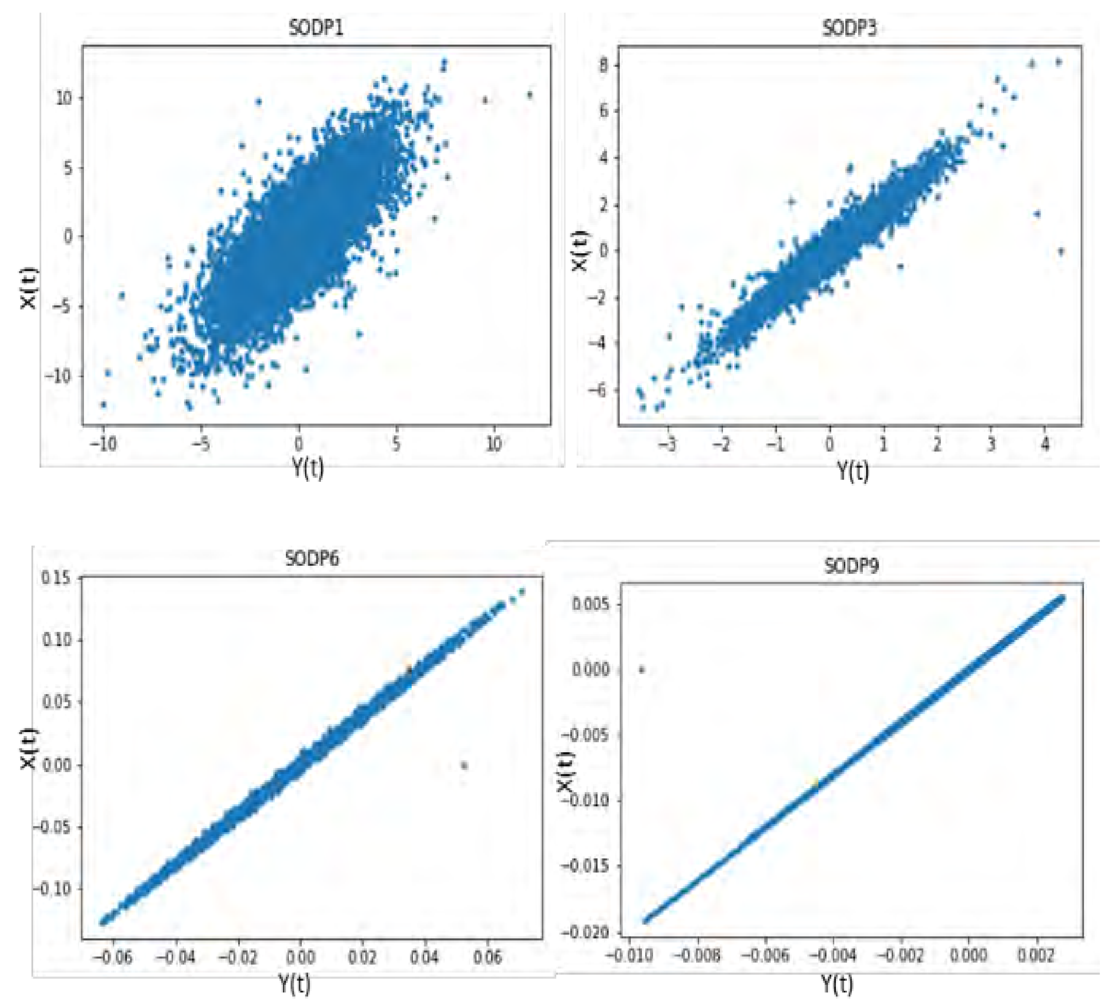


- After SVM Classifier is trained with the labeled dataset, it can be used to predict the emotion quadrant in any newly acquired EEG signal from another source.

Second Order Difference Plot

- EEG a reliable source for research on emotion in current times, as it cannot be disguised.
- EEG signals are first windowed in time domain.
- The original signals are first divided into reducing units of time and second order difference plots have been constructed from them.
- The second order difference plot of resulting windowed signals is computed. This technique helps in the analytical study of correlation between consecutive rate values in a time series.

- The second order difference plot of signal x(t) can be obtained by plotting X(t) against Y(t)
- X(t)=x(t+1)-x(t) ;
- Y(t)=x(t+2)-x(t+1)



Feature Extraction

- After pre-processing, the features extracted from the second order difference plot are Area, Mean and Central Tendency Measure.
- Area calculates the area of the elliptic region of the second order difference plot.
- For a given radius r around the origin of the second order difference plot, central tendency measure is the ratio of the number of points within the radius, to the total number of points in plot.
- Mean distance D(r) is calculated by first evaluating the mean distance of each of the points d(i) lying within the circular radius r.

- $CTM(r) = \frac{[\sum_{i=1}^{n-2} \delta(d(i))]}{n-2}$ where, $\delta(d(i))$ is 1 if $([x(i+2)-x(i+1)]^2 + [x(i+1)-x(i)]^2)^{0.5} < r$

  and otherwise $\delta(d(i))$ is 0.

Classifier Training and Evaluation

- SVM and hyper parameterized SVM has shown the variations in results in almost all the quadrants.
- SVM Classification for Channel selection is done as per different brain regions.
- Performance metrics from multiclass classifications were compared with that of multiple binary classifications.
- Statistical performances of the classifier have been evaluated by computing F1-Score and accuracy.
- The maximum accuracy of 88.12% was achieved for the classification of emotions in the quadrant of Low Dominance High Valence vs Rest.
- Test accuracy got for several SVM classifications, is as follows:

Emotion/ Quadrant	SVM	SVM (Hyper Parameter Tuning)	SVM (Region Wise Best Score)	SVM (Multiple Binary Classification)
Arousal	54.5	80	79.12	79.12
Valence	67.4	76	79.78	79.78
Dominance	66.9	80	79.78	79.78
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Valence - Dominance	58.9	66	69.04	88.13
Arousal-Dominance	59.2	64	65.44	81.25

Results and Discussion

- The combination of windowed signals along with Second Order Difference Plot, from EEG data, gives significant results which have not yet been explored in emotion recognition research.
- Literature doesn't show considerable work in emotion recognition from EEG data in the quadrant of Dominance.
- In the quadrant of valence-dominance, we have achieved maximum accuracy of 88.13% and in arousal-dominance the max was 81.25%.
- SVM is the most commonly used classifier in emotion recognition through EEG signals, but the maximum noted accuracy is 86.28% by Zhang et. al. in DEAP dataset.
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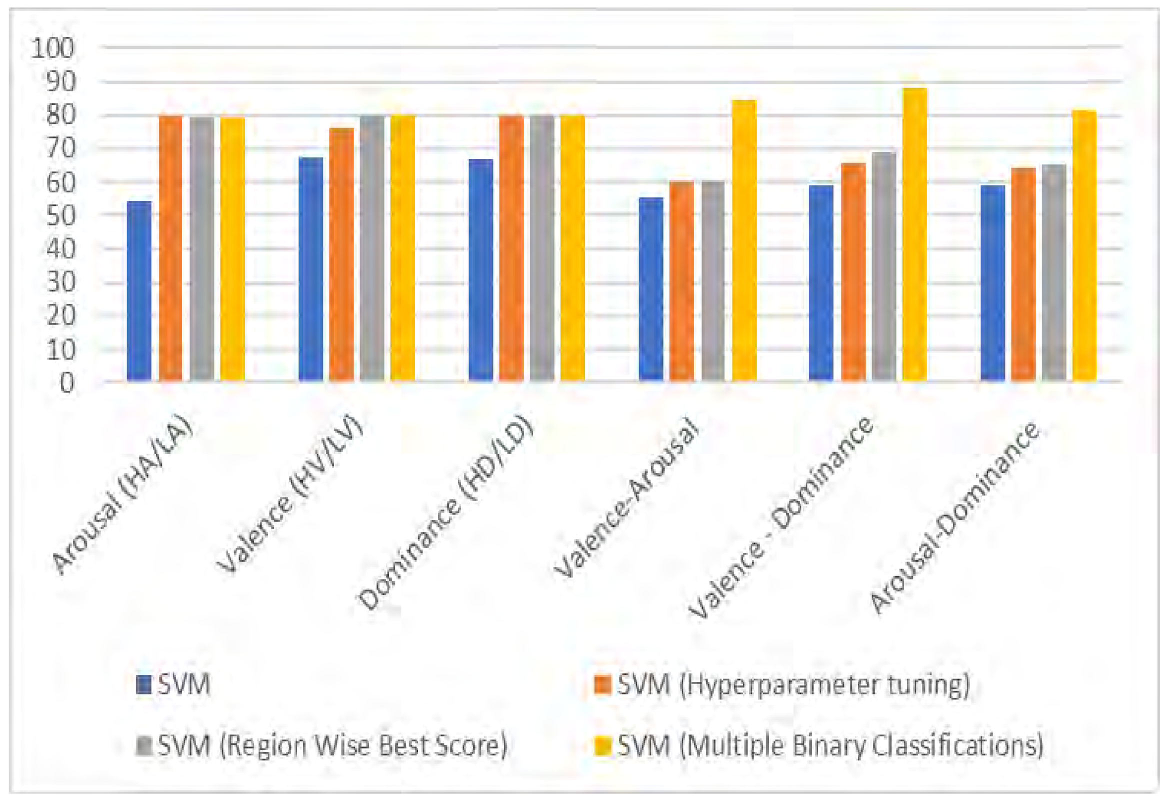

Conclusion and Future Scope

- An entirely automated Python package was made through this project for data pre-processing, feature extraction, with available trained models for classification of emotion.
- Preprocessing of a single EEG channel data was taking 7 mins earlier, which was improved to 3.2 mins by using optimized code and hyper parameters tuning.
- This would serve as an initial working prototype for healthcare monitoring or emotional recognition systems.
- The scope for automatic emotion recognition systems is growing with availability of data and advancement of technology.
- General healthcare systems and regular employee metal health monitoring in organizations is becoming the norm.
- Such systems can help reduce the workload of professionals, and assist in monitoring the public mental health.