# AM5011 Course Project Report

## Study of Emotional Arousal to determine Sense of Presence in VR

***B Swati***

***ED19B005***

## Objective:

Identification of emotional arousal in the VR environment by clustering of the eye-tracking features, which will in turn prove the sense of presence in VR.

## Introduction:

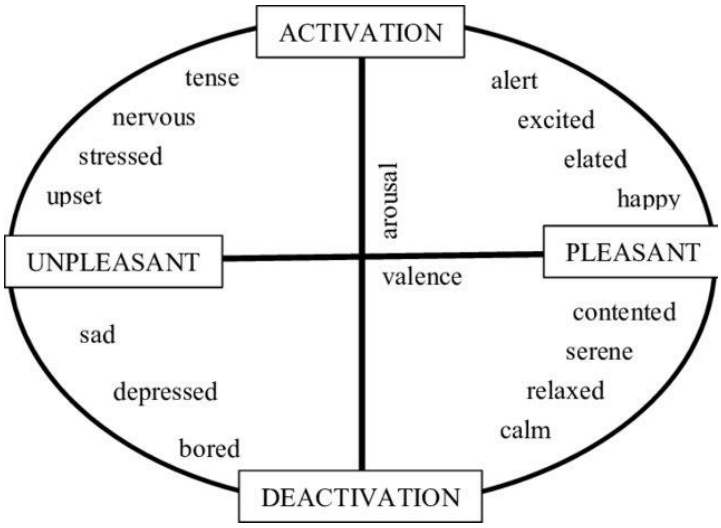
The VR environment serves to provide an immersive and interactive experience for the user. While the design of the interaction system is done while the VR environment is being developed, immersivity is more implicit. Immersion is an objective metric involving the user's emotions and attachment to the VR environment. Sense of Presence (SoP), often associated with immersion, is subjective with regards to the feeling of the user being present in the VR environment. Sense of Presence is measured by cognitive, emotional and behavioural responses. The project is focused on the emotional response of the user in the VR environment, which in turn can be related to Sense of Presence in VR environment.

The experiments to study the emotional response are done by studying the various physical and physiological parameters. The correlation in the parameters is analysed in the recognition of the emotional responses to the stimulus.

## Literature Survey:

There are numerous experiments which have been conducted to study the arousal and valence of emotions the participants feel during the VR experience. The setup included the emotional stimulus and the recording of the reaction. The physiological features recorded included PPG, eye metrics, ECG, EEG, etc. The participants were made to answer questionnaires on their feelings after the VR exposure. The recorded features and the questionnaires were used to map the value of emotional arousal and valence and classify the emotion accordingly. Machine Learning and Deep Learning models were used for these purposes. More the number of physiological signals is considered, more the accuracy of the trained model. The most commonly used model is the Support Vector Machines.

The circumplex model of affect is used to classify these emotions. Emotional arousal is an important sign indicating sense of presence.




The pupils are observed to dilate in case of emotional arousal. The negative emotions dilate the pupil more than the positive emotions.

There are a lot of datasets made available online with open access. These datasets are used in the various experiments and can be used to train the models that are developed in the future.

## Method:

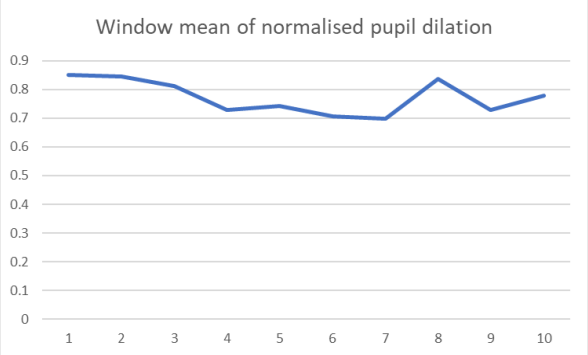
The participants in the experiment were made to undergo a VR scenario. They eye tracking features were extracted like the blink rate and pupil dilation. Normalised pupil diameter is considered in the project. All the values are got from the experiment conducted in the Haptics lab. The given data is divided into 10 windows, based on the conditions. The classification of each window based on the arousal was aimed by the study.

The data was used to classify using the clustering algorithms. The correlation of the blink rate with the pupil dilation was analysed. Data was available for 185 participants who underwent the experiment. The given data was divided into two sets, for testing and training. The training set had 80% of the given dataset.

The training set was clustered with k=2. With the results of the clustering, the windows were classified into either class by pure majority. The test data was fed into the model. And based on the majority of the data classified in each window, the test data windows were also assigned classes. The window classes of both the test and train data are compared.

## Results:

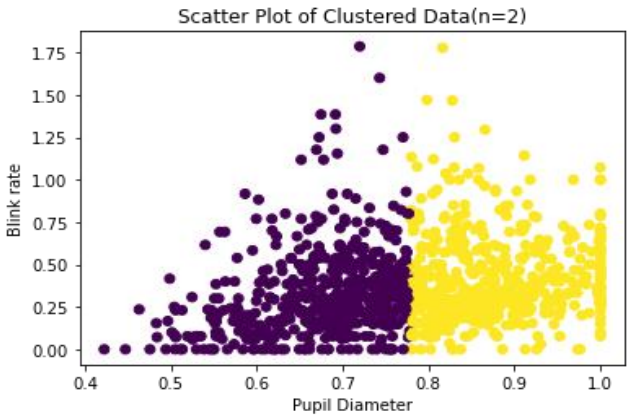
### Plotting the normalised pupil dilation data:




Keeping 0.8 as threshold, assigning classes to windows:

| Window | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Class | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

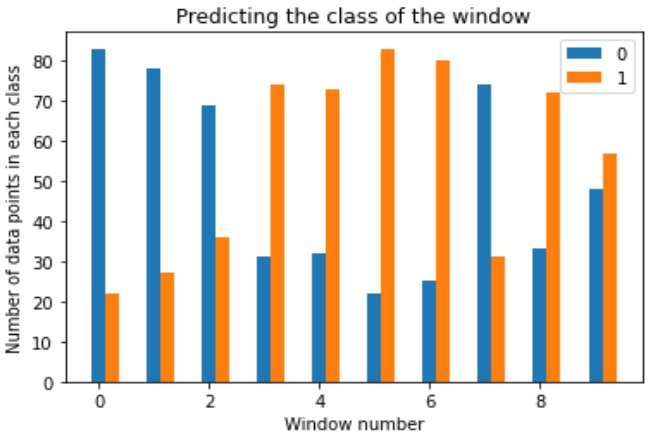
## Clustering of data:




**n=2**

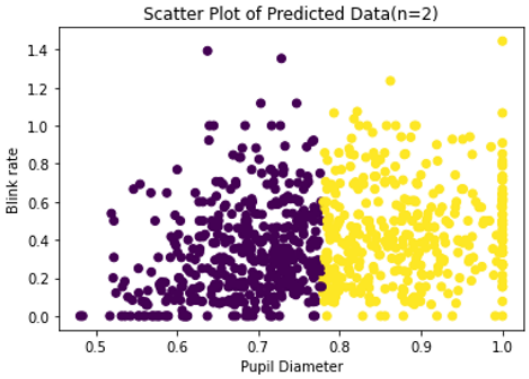
| Window | Class 0 | Class 1 |
|---|---|---|
| 1 | 22 | 83 |
| 2 | 27 | 78 |
| 3 | 36 | 69 |
| 4 | 74 | 31 |
| 5 | 73 | 32 |
| 6 | 83 | 22 |
| 7 | 80 | 25 |
| 8 | 31 | 74 |
| 9 | 72 | 33 |
| 10 | 57 | 48 |

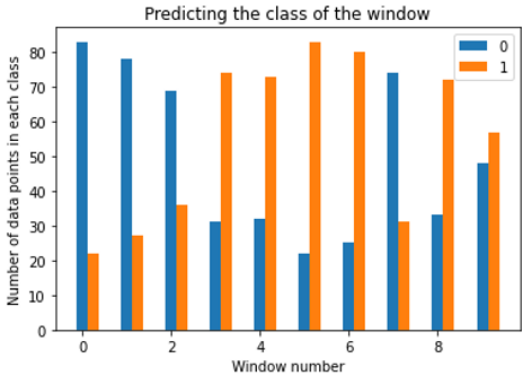
## Class Prediction for the windows:




| Window | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Class | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

## Result from test data:




| Window | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Class | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

## Inclusion of VR concepts from the course:

Eye Tracking, Sense of Presence, Evaluation of VR, Immersion.

## Discussion:

From the plots, we can see that the model had divided the data based on an approximate straight line parallel to the Y-axis. We can say that thus the blink rate did not have much significance in the classification. The classes are similar to the ones that are made by the plot of mean of the normalised pupil diameter data of the windows. Thus, pupil diameter is a major factor for the determination of the emotional arousal.

There is an observable emotional arousal in all the windows. The training and testing showed the same classification of the windows. This shows that there is a pattern in the pupil dilation and thus a different level of emotional arousal in different windows. This is a proof of Sense of presence in VR.

## Conclusion:

Users of VR experience emotional arousal to the immersion into the VR environment. The emotional arousal can be measured by the eye tracking, with the user using the HMD. The scope of this can be extended to develop a model which can detect emotions. The application of such a model is wide and interdisciplinary.

I thank Lokeshwaran for the data and his support for the execution of the project.

## References:


- Bublea, A., & Caleanu, C. D. (11 2020). *Deep Learning based Eye Gaze Tracking for Automotive Applications: An Auto-Keras Approach*. doi:10.1109/ISETC50328.2020.9301091
- Campion-Vincent, V. (n.d.). *The tell-tale eye (Analysis of a myth, photography, murder, retinal images, evidence) Review of a book View project Conspiracy Theories View project*. Retrieved from https://www.researchgate.net/publication/298939714

- Sipatchin, A., Wahl, S., & Rifai, K. (2 2021). Eye-tracking for clinical ophthalmology with virtual reality (Vr): A case study of the htc vive pro eye's usability. *Healthcare (Switzerland)*, *9*. doi:10.3390/healthcare9020180
- Yeom, D., Choi, J. H., & Zhu, Y. (1 2019). Investigation of physiological differences between immersive virtual environment and indoor environment in a building. *Indoor and Built Environment*, *28*, 46–62. doi:10.1177/1420326X17731945
- Persiani, S. G. L., Kobas, B., Koth, S. C., & Auer, T. (1 2021). Biometric data as real-time measure of physiological reactions to environmental stimuli in the built environment. *Energies*, *14*. doi:10.3390/en14010232
- Imaoka, Y., Flury, A., & de Bruin, E. D. (9 2020). Assessing Saccadic Eye Movements With Head-Mounted Display Virtual Reality Technology. *Frontiers in Psychiatry*, *11*. doi:10.3389/fpsyt.2020.572938
- Ben, M., & Lachiri, Z. (2017). Emotion Classification in Arousal Valence Model using MAHNOB-HCI Database. *International Journal of Advanced Computer Science and Applications*, *8*. doi:10.14569/IJACSA.2017.080344
- Zhu, Y., Zhai, G., & Min, X. (11 2018). The prediction of head and eye movement for 360 degree images. *Signal Processing: Image Communication*, *69*, 15–25. doi:10.1016/j.image.2018.05.010
- Costela, F. M., & Woods, R. L. (8 2019). A free database of eye movements watching "Hollywood" videoclips. *Data in Brief*, *25*, 103991. doi:10.1016/j.dib.2019.103991
- Magdin, M., Balogh, Z., Reichel, J., Francisti, J., Koprda, Š., & György, M. (12 2021). Automatic detection and classification of emotional states in virtual reality and standard environments (LCD): comparing valence and arousal of induced emotions. *Virtual Reality*, *25*, 1029–1041. doi:10.1007/s10055-021-00506-5
- Souza, V., Maciel, A., Nedel, L., & Kopper, R. (11 2022). Measuring Presence in Virtual Environments: A Survey. *ACM Computing Surveys*, *54*, 1–37. doi:10.1145/3466817
- Oliva, M., & Anikin, A. (12 2018). Pupil dilation reflects the time course of emotion recognition in human vocalizations. *Scientific Reports*, *8*, 4871. doi:10.1038/s41598-018-23265-x
- Diemer, J., Alpers, G. W., Peperkorn, H. M., Shiban, Y., & MÃ¼hlberger, A. (1 2015). The impact of perception and presence on emotional reactions: a review of research in virtual reality. *Frontiers in Psychology*, *6*. doi:10.3389/fpsyg.2015.00026
- Jicol, C., Wan, C. H., Doling, B., Illingworth, C. H., Yoon, J., Headey, C., … O'Neill, E. (5 2021). *Effects of Emotion and Agency on Presence in Virtual Reality*. 1–13. doi:10.1145/3411764.3445588
- Dan, E. L., Dinsoreanu, M., & Muresan, R. C. (5 2020). *Accuracy of Six Interpolation Methods Applied on Pupil Diameter Data*. 1–5. doi:10.1109/AQTR49680.2020.9129915
- Korda, A. I., Giannakakis, G., Ventouras, E., Asvestas, P. A., Smyrnis, N., Marias, K., & Matsopoulos, G. K. (1 2021). Recognition of Blinks Activity Patterns during Stress Conditions Using CNN and Markovian Analysis. *Signals*, *2*, 55–71. doi:10.3390/signals2010006
- Abbott, D., Shirali, Y., Haws, J. K., & Lack, C. W. (9 2017). Biobehavioral assessment of the anxiety disorders: Current progress and future directions. *World Journal of Psychiatry*, *7*, 133–147. doi:10.5498/wjp.v7.i3.133
- Lim, J. Z., Mountstephens, J., & Teo, J. (4 2020). Emotion Recognition Using Eye-Tracking: Taxonomy, Review and Current Challenges. *Sensors*, *20*, 2384. doi:10.3390/s20082384
- Skaramagkas, V., Giannakakis, G., Ktistakis, E., Manousos, D., Karatzanis, I., Tachos, N., … Tsiknakis, M. (2021). Review of eye tracking metrics involved in emotional and cognitive processes. *IEEE Reviews in Biomedical Engineering*, 1–1. doi:10.1109/RBME.2021.3066072
- Zheng, L. J., Mountstephens, J., & Teo, J. (12 2020). Four-class emotion classification in virtual reality using pupillometry. *Journal of Big Data*, *7*, 43. doi:10.1186/s40537-020-00322-9

- Riches, S., Elghany, S., Garety, P., Rus-Calafell, M., & Valmaggia, L. (4 2019). Factors Affecting Sense of Presence in a Virtual Reality Social Environment: A Qualitative Study. *Cyberpsychology, Behavior, and Social Networking*, *22*, 288–292. doi:10.1089/cyber.2018.0128