

Table. 1. Assignment of the driving style to all the vehicles based on maximum labels

Vehicle ID	Total Frames	Label 0	Label 1	Label 2	Max. frame
2	437	35	240	162	1
4	351	63	125	163	2
5	452	44	245	163	1
6	357	82	112	163	2
20	414	68	183	163	1
25	436	97	176	163	1
26	438	74	201	163	1
27	432	107	162	163	2
62	431	165	103	163	0
63	305	177	0	128	0
64	414	161	90	163	2
67	409	167	79	163	0
69	504	258	83	163	0
77	494	273	58	163	0
78	473	242	68	163	0
79	432	209	60	163	0

Table. 2. Comparison of aggressive, moderate and traditional drivers

Driving Style		velocity	Acceleration	Jerk	Space Headway	Time Headway
Aggressive	mean	49.08	0.57	5.62E-17	60.82	1.31
	min	24.40	-11.20	-213.7	0.00	0.00
	max	95.30	11.20	224	257.37	5.60
Moderate	mean	48.60	0.51	-1.68E-17	82.53	1.73
	min	27.78	-11.20	-195.2	0.00	0.00
	max	77.47	11.20	224	329.31	6.81
Traditional	mean	45.55	0.39	-6.29E-17	85.85	3.06
	min	0.00	-11.20	-224	0.00	0.00
	max	75.28	11.20	224	408.24	11.99

Figure 7 depict the comparison graph of aggressive, moderate & traditional vehicle on different feature like velocity, acceleration, jerk, space and time headway. The mean value is taken in to the consideration for comparison among all the categories. For aggressive vehicle, the velocity, acceleration, jerk is higher while space and time

Headway is smaller as compared among all the categories of the vehicle i.e. moderate and traditional. All the value of moderate vehicle lie in between aggressive and traditional while the values obtained for the traditional vehicle is inverse of the aggressive vehicles.

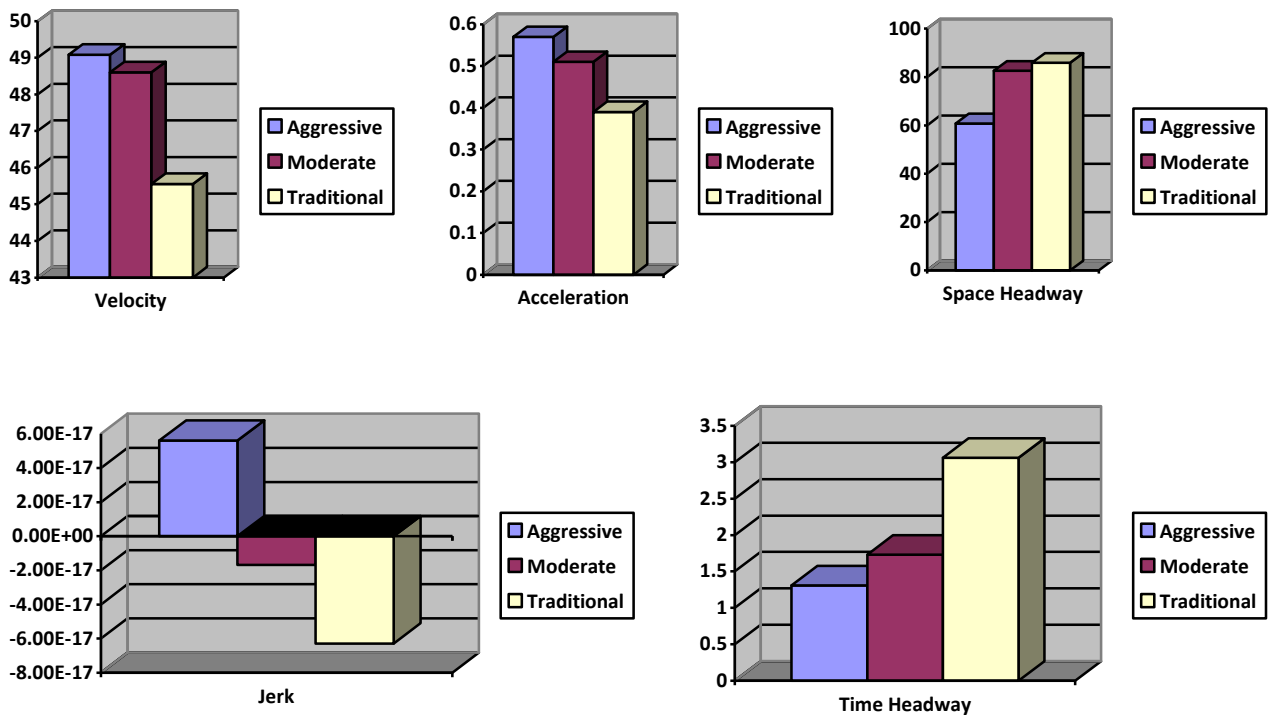


Fig. 7. Comparison graph of aggressive, moderate, traditional vehicle on different feature like velocity, acceleration, jerk, space and time headway

5. Conclusion

This research aimed to categorize vehicle driving styles by analyzing trajectory data. Principal Component Analysis (PCA) is used to streamline characteristic indexes, reducing them to two components that represented all features. The "Elbow rule" and Silhouette methods were utilized to identify the optimal number of categories, and the K-means clustering algorithm was applied to cluster vehicle driving styles. Finally, the driving styles were divided into aggressive, moderate and traditional styles. The study revealed that aggressive driving is characterized by higher velocity, acceleration, and jerk, along with lower space and time headway. The proposed unlabeled data based driving style classification method will be extended to other driving scenarios and new dataset.

References

- [1] D. F. Xie, Z. Z. Fang, B. Jia, et al., "A data-driven lane-changing model based on deep learning," *Transportation Research Part C: Emerging Technologies*, vol. 106, pp. 41-60, Jul. 2019.
- [2] J. Zhang, G. Zhen, H. Jia and H. Wei, "Trajectory Prediction of Surrounding Vehicles for Autonomous Vehicle Using POMDP Method," 2022 2nd International Conference on Computer Science, Electronic Information Engineering and Intelligent Control Technology (CEI), Nanjing, China, 2022.
- [3] J. Lee et al., "Categorizing Driving Styles of Surrounding Vehicles Using K-Means Clustering," *IEEE Transactions on Intelligent Transportation Systems*, vol. 19, no. 5, pp. 1548-1557, May 2018.
- [4] Y. Chen et al., "Hierarchical Clustering for Categorizing Driving Styles Based on Speed, Acceleration, and Deceleration Patterns," *IEEE Transactions on Vehicular Technology*, vol. 68, no. 8, pp. 7577-7588, Aug. 2019.
- [5] Q. Wang et al., "Categorization of Driving Styles Using DBSCAN Algorithm Based on Speed, Acceleration, and Lateral Position," *IEEE Access*, vol. 8, pp. 97879-97890, May 2020.
- [6] H. Zhang et al., "Hybrid Clustering Approach for Driving Style Categorization Using K-Means and Gaussian Mixture Model," *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 3, pp. 1543-1552, Mar. 2021.
- [7] T. Xu, X. Zhang and Y. K. Zhang, "Safety Orientation Classification of truck drivers based on AdaBoost algorithm," *Journal of Safety and Environment*, vol. 19, pp. 1273-1281, Aug. 2019.
- [8] H. Jin and M. Lv, "Research on Driving Style in starting Condition based on Improved Fisher

- criterion," *Transactions of Beijing Institute of Technology*, vol. 40, pp. 262-266, Mar. 2020.
- [9] Punzo, Vincenzo, Maria Teresa Borzacchiello, and Biagio Ciuffo. "On the assessment of vehicle trajectory data accuracy and application to the Next Generation Simulation (NGSIM) program data." *Transportation Research Part C: Emerging Technologies* 19.6 (2011): 1243-1262.
- [10] Coifman, Benjamin, and Lizhe Li. "A critical evaluation of the Next Generation Simulation (NGSIM) vehicle trajectory dataset." *Transportation Research Part B: Methodological* 105 (2017): 362-377.
- [11] Y. Xing, C. Lv and D. Cao, "Personalized Vehicle Trajectory Prediction Based on Joint Time-Series Modeling for Connected Vehicles," in *IEEE Transactions on Vehicular Technology*, vol. 69, no. 2, pp. 1341-1352, Feb. 2020
- [12] Iacono, Teresa, Bould, Emma, BeadleBrown,"An exploration of communication within active support for adults with high and low support needs". *Journal of Applied Research in Intellectual Disabilities*, (2019) 32 (1). pp. 61-70.
- [13] S. Wen, X. G. Shahd Omar, X. Jin and Z. He, "Analysis of Vehicle Driving Styles at Freeway Merging Areas Using Trajectory Data," 2022 IEEE 25th International Conference on Intelligent Transportation Systems (ITSC), Macau, China, 2022, pp. 3652-3656
- [14] S. R. Jambula, S. C. Mathi, S. N. Polu, K. G. O. JM, V. P. Mateti and S. Yadav, "Enhanced UAV with Image-Driven Concrete Crack Detection," 2023 7th International Conference on Electronics, Communication and Aerospace Technology (ICECA), Coimbatore, India, 2023, pp. 1730-1737
- [15] M. P. Kiyindou, S. E. Sunday and Z. Hong, "Enhancing the Evaluation Performance of Convolutional Neural Networks-Based Vehicle Classification Systems," 2023 International Conference on the Cognitive Computing and Complex Data (ICCD), Huaian, China, 2023, pp. 68-72.
- [16] J. H. Yang, D. J. Kim and C. C. Chung, "Lane Change Intention Inference of Surrounding Vehicle: Comparative Study on Relevance Vector Machine (RVM) and Support Vector Machine (SVM)," 2021 21st International Conference on Control, Automation and Systems (ICCAS), Jeju, Korea, Republic of, 2021, pp. 1580-1585
- [17] S. Liu, F. Ren, G. Yang, D. He and Y. Liu, "Employing Deep Unsupervised Learning Method to Identify Testing Scenarios for Automated Vehicles," 2023 10th International Conference on Dependable Systems and Their Applications (DSA), Tokyo, Japan, 2023, pp. 628-635,
- [18] A. Adnan, G. M. Mahbubur Rahman, M. M. Hossain, M. S. Mim and M. K. Rahman, "A Deep Learning Based Autonomous Electric Vehicle on Unstructured Road Conditions," 2022 IEEE 12th Symposium on Computer Applications & Industrial Electronics (ISCAIE), Penang, Malaysia, 2022, pp. 105-110.