Deep Learning Techniques Utilized for Assessing CO_2 Emissions of Swiss Passenger Cars

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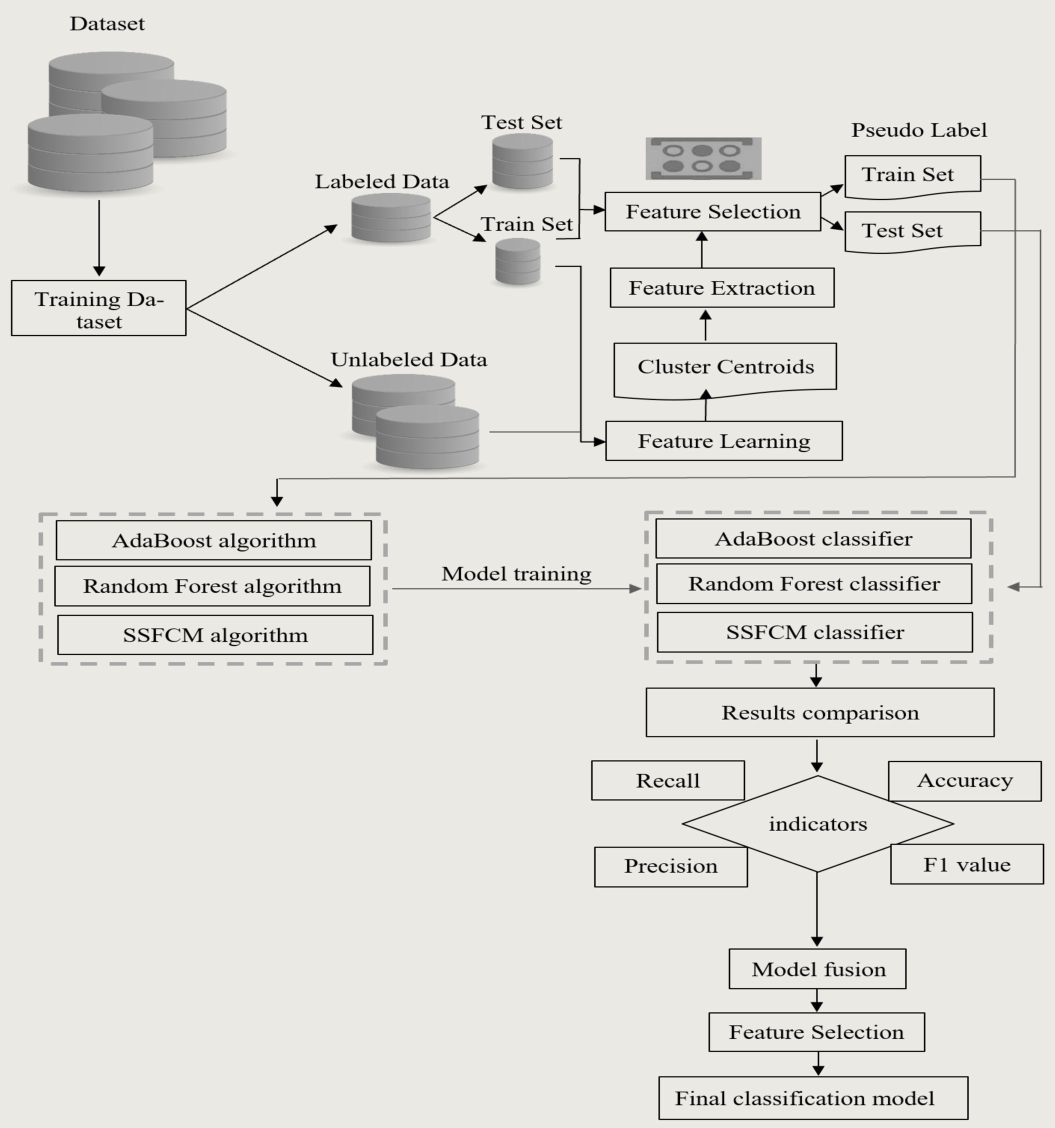
Introduction

The overall level of emissions from the Swiss passenger cars is strongly dependent on the fleet composition. Despite technology improvements, the Swiss passenger cars fleet remains emissions intensive. To analyze the root of this problem and evaluate potential solutions, this study applies deep learning techniques to evaluate the inter-class (namely micro, small, middle, upper middle, large and luxury class) and intra-class (namely sport utility vehicle and non-sport utility vehicle) differences in CO_2 emissions. Since the division of vehicles into segments by experts is not standardized and therefore not always uniform, and some vehicle models have recently positioned themselves as "crossovers" between established vehicle categories, it has become increasingly difficult and inaccurate to segment the vehicle population using conventional classification methods. The development of a mathematical approach to accurately segment passenger vehicles is essential for determining the real CO_2 emissions from road traffic in the future. While road traffic has so far had its own energy system, which was comparatively easy to assess in terms of CO_2 emissions, increasing electrification of road traffic will difficult the distinction of energy consumption from road traffic and other stationary energy uses. Based on this novel approach, we can then predict accurate segment-based CO_2 emissions, which allows for detailed analyses of the main factors influencing the average fleet CO_2 emissions. Our results show that the proposed method is a viable and effective to categorize vehicles based on their technical, emission and dimensional features.

In this study, by segmenting the passenger vehicles based on technical and dimensional characteristics, we aim to better understand the impact of inter-class and intra-class variations to the passenger vehicle fleet CO_2 footprint.

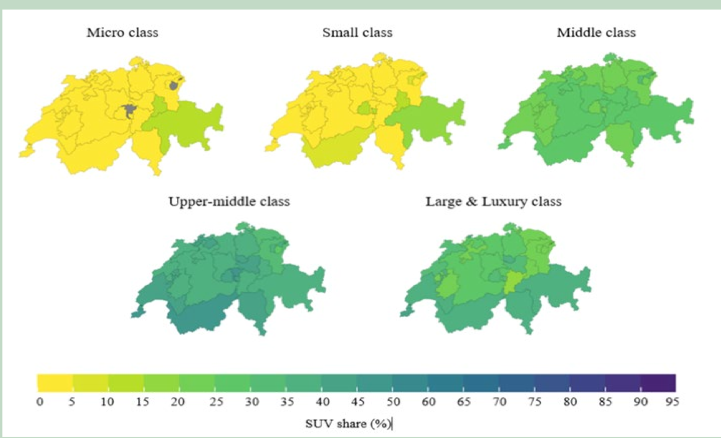
Methods

- This study focuses on utilizing "Deep" for deep correlation between supervised and unsupervised data with multi clusters and deep correlation between Deep semi supervised fuzzy C-means (SSFCM) clustering and feature techniques.
- Explored several semi-supervised machine learning algorithms and compared their performance.
- Used feature learning and feature extraction technique for representation learning in high-dimensional datasets with high-level uncertainties.
- Model fusion method combines SSFCM and state-of-the-art methods using majority voting to achieve higher classification accuracy than individual classifiers.



Discussion

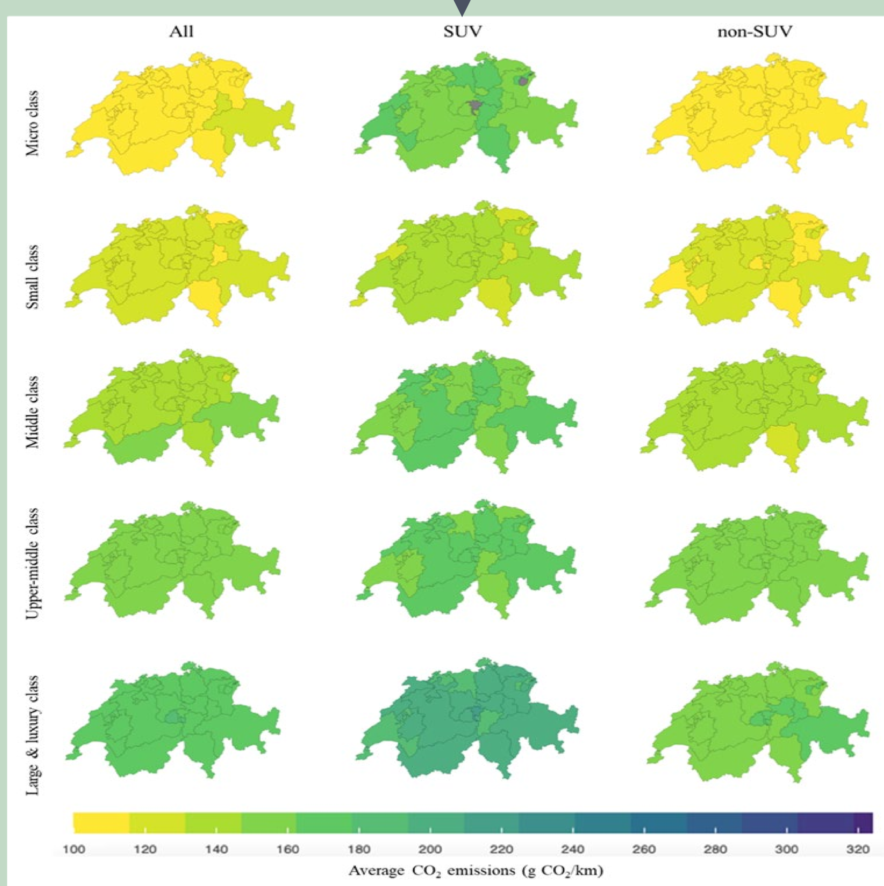
The spatial distribution of the share of SUV vehicles among different vehicle classes reveals that, in general, the proportion of SUVs within each class is higher in the southern and central cantons.



Although the share of SUVs in the micro class is very small, SUV vehicles generally exhibit higher CO_2 emissions than non-SUVs. This difference is particularly noticeable in the case of micro class vehicles, indicating that shifting from a non-SUV middle class vehicle to a micro class SUV could lead to an increase in CO_2 emissions..

Experiment results demonstrate that the large variabilities in the average CO_2 emissions of different vehicle classes. While a shift of the fleet towards smaller vehicles is likely to diminish CO_2 emissions, the emissions intensity could be more effectively reduced by shifting the vehicles proportion within each class.

In general, the spatial distribution of the CO_2 emissions for each vehicle class and sub-class is quite homogeneous, and there are no significant trends between different regions of the country.



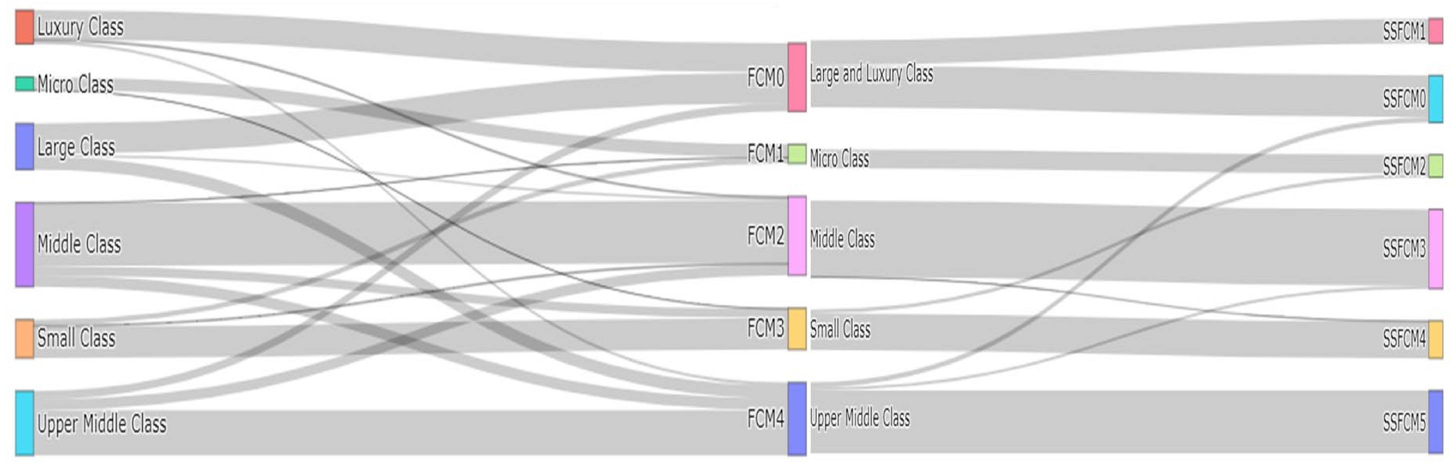
Spatial distribution of the average CO_2 emissions (in g CO_2/km) among different vehicle classes and sub-classes.

Results

This paper is an extension of a previous work originally focused on developing a machine learning based methodology for the mathematical inter-class and intra-class segmentation of passenger vehicles [1-2]. The experimental results show that the single clustering models using SSFCM, random forest and AdaBoost algorithms and the fusion model all enhance the classification accuracy in comparison to the traditional FCM algorithm (overall accuracy of 79%). Among them, the SSFCM algorithm can extract richer information from the vehicle dataset and obtain more discriminative recognition rates than other classifiers do.

Method	Accuracy rate	Precision rate	Recall	F1
SSFCM	0.954	0.953	0.881	0.916
AdaBoost	0.891	0.871	0.823	0.846
Random Forest	0.902	0.89	0.86	0.875
Hard Voting	0.921	0.935	0.871	0.902
Soft Voting	0.942	0.956	0.878	0.915

Sankey diagram of inter-class vehicle classifications of dataset. The colors indicate the vehicle classification by Swiss expert segmentation (left), traditional FCM algorithm (middle) and SSFCM approach (right)

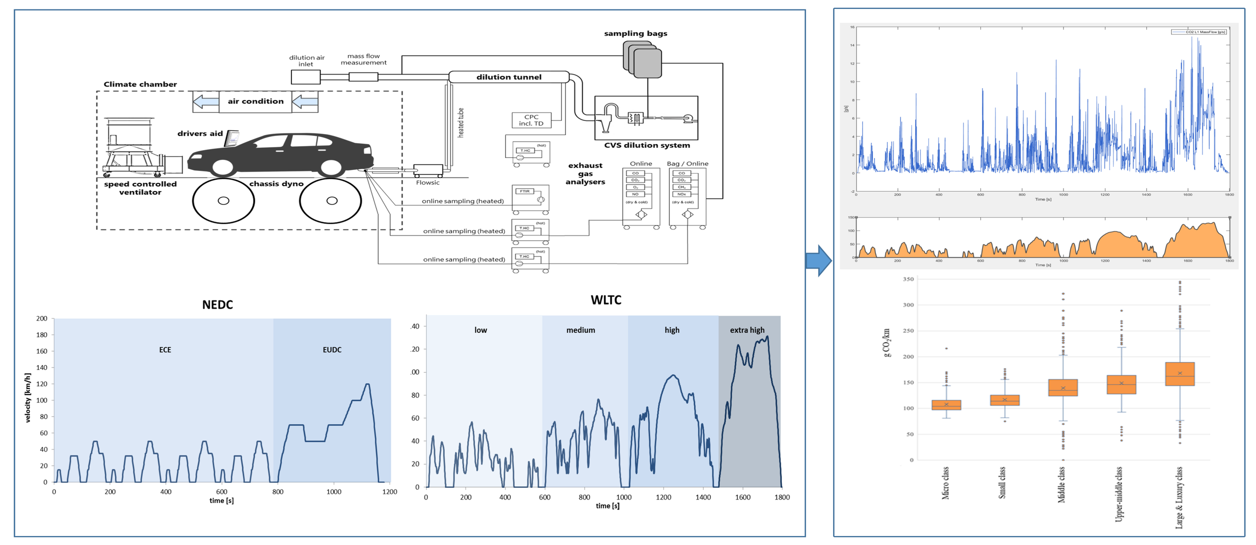


Assumption:
H0: Feature extraction technique has no impact on classification
H1: Feature extraction technique enhances classification

Prediction accuracy and verification clustering results

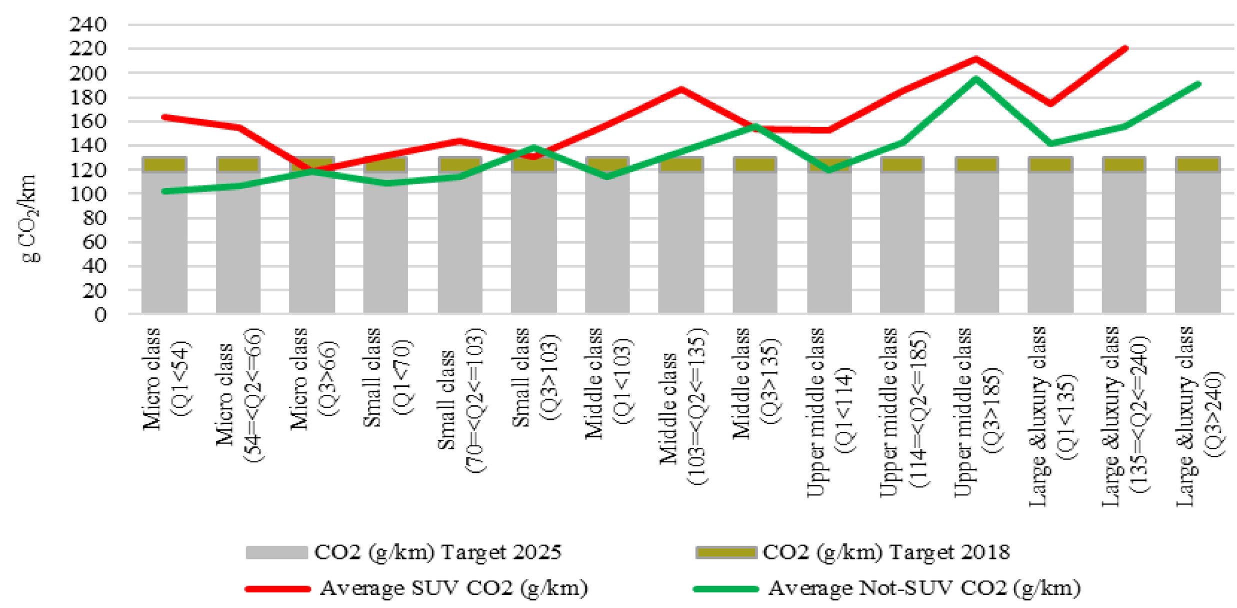
Method	Training accuracy	Test accuracy
SSFCM	0.952	0.904
AdaBoost	0.781	0.715
Random Forest	0.903	0.837

Using the SSFCM model, we estimate the average CO_2 emissions of all new passenger vehicles registered in 2018 to be 138.9 g CO_2/km, which only deviates by 1.1% from the official estimate of SFOE of 137.8 gCO_2/km.



Distribution of the CO_2 emissions among the different vehicle classes

The overall level of emissions from the Swiss passenger cars is strongly affected by the fleet composition, which is shifting in time between classes (from the upper-middle class to the large and luxury classes) and within each class (from non-SUV to SUV).



New registered passenger cars average CO_2 emissions intensity based on the interquartile power range (Q) by both vehicle inter and intra-class classification

Conclusion

The proposed approach enables accurate automated vehicle classification of large databases, which in turn facilitates the analysis of fleet changes. Another important advantage of the clustering based mathematical segmentation is that it removes the subjectivity factors affecting expert-based segmentations, reducing classification errors and making databases from across the world comparable. Finally, the automatized clustering approach also reduces classification costs and training time.

Moreover, the results indicate that the combination of the inter-class and intra-class classification provides crucial insights for developing fleet transformation strategies to decarbonize the passenger vehicle fleet.

References

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3. Niroomand, N., Bach C., Elser M., 2021. Segment-based CO_2 Emission Evaluations from Passenger Cars based on Deep Learning Techniques, IEEE Access, 9, 166314-166327.