Zhenyi XU, Renjun WANG, Yang CAO, Yu KANG, 2023. High-emitter identification for heavy-duty vehicles by temporal optimization LSTM and an adaptive dynamic threshold. *Frontiers of Information Technology & Electronic Engineering*, 24(11):1633-1646. https://doi.org/10.1631/FITEE.2300005

High-emitter identification for heavy-duty vehicles by temporal optimization LSTM and an adaptive dynamic threshold

Key words: High-emitter identification; Temporal optimization; On-board diagnostic device (OBD); Dynamic threshold

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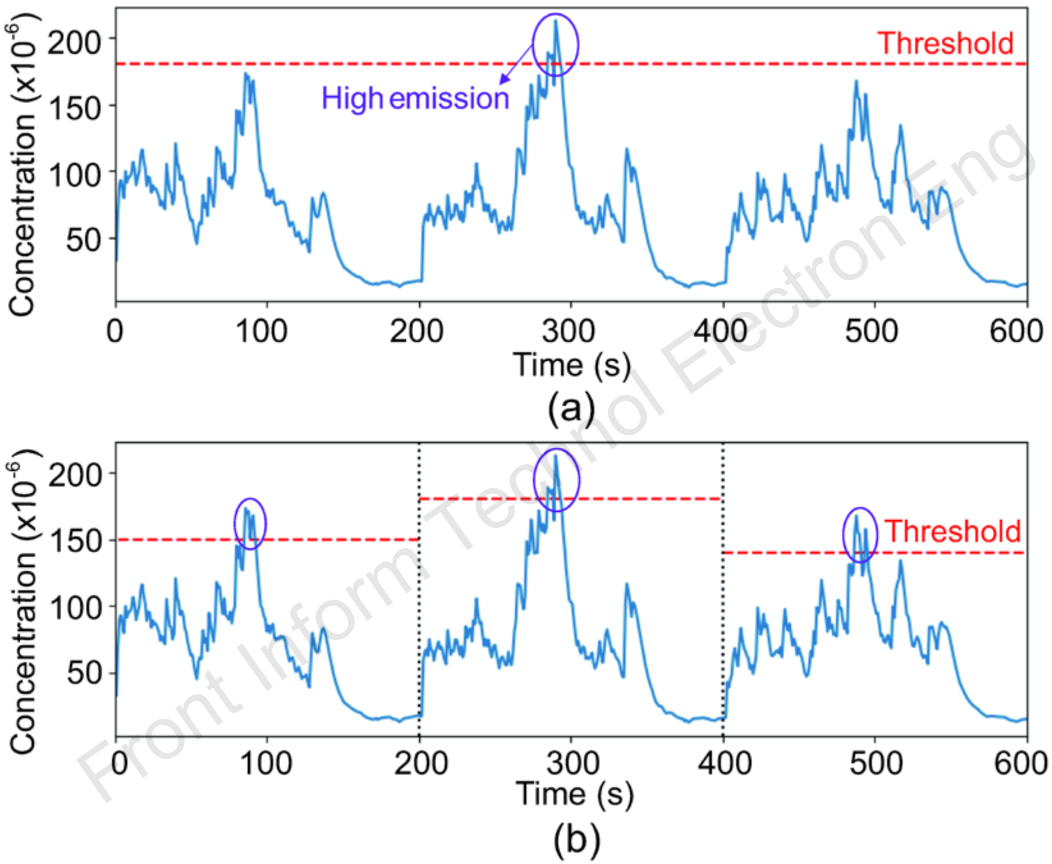
Motivation

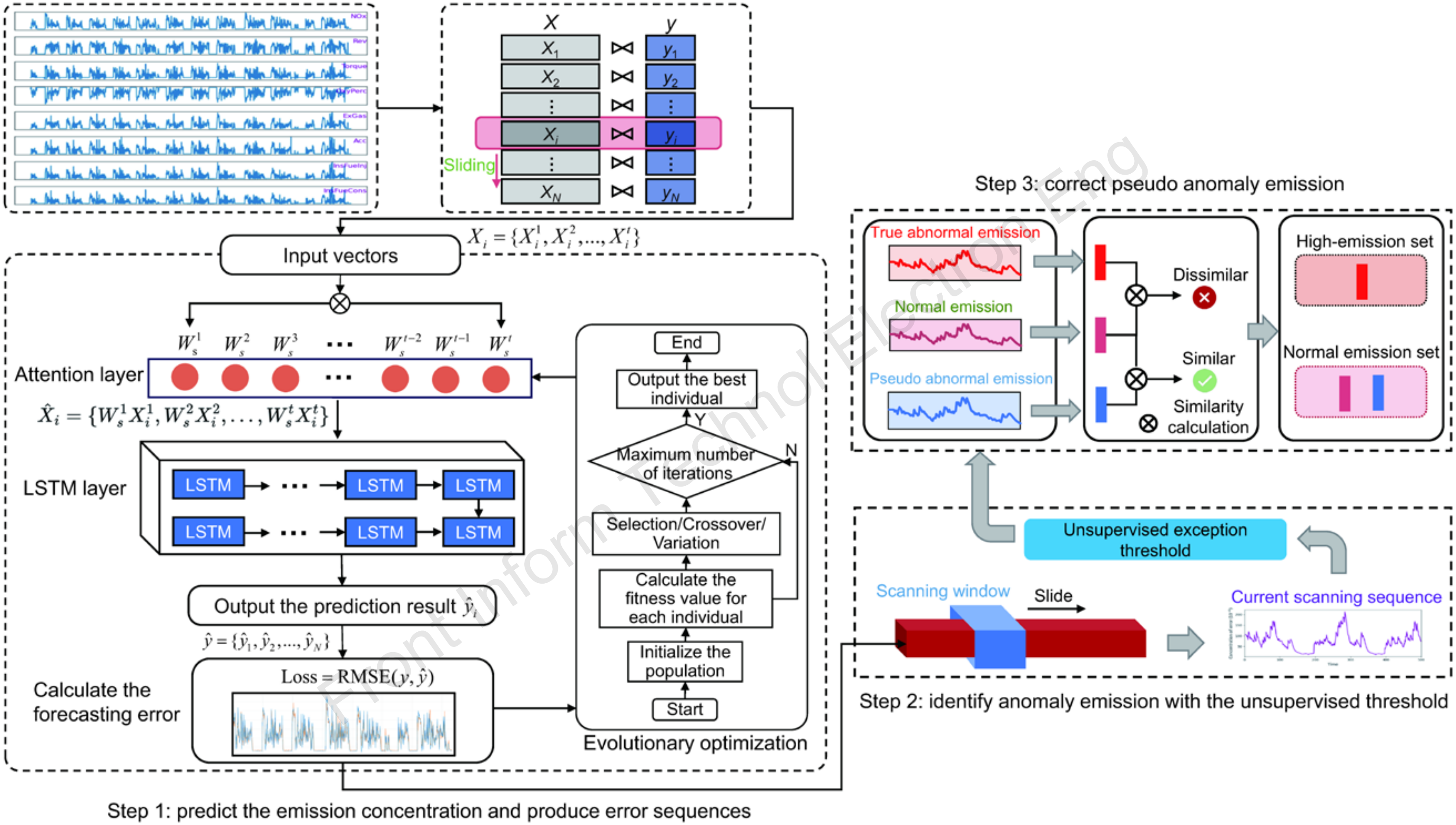


Different thresholds for high-emission identification: (a) constant threshold; (b) dynamic threshold. When the time span of driving conditions is long enough, the constant threshold cannot capture high emissions as accurately as the dynamic threshold

Main idea

- We establish an emission prediction model, long short-term memory (LSTM) based on evolutionary algorithm optimization.
- A dynamic anomaly threshold operator is proposed to identify high-emission samples in changing driving conditions, where the decision threshold for high emissions will change adaptively as the driving conditions change with time.
- An anomaly pruning strategy is introduced that calculates the similarity between normal and abnormal sequences, to correct the possible pseudo anomalous emissions in the identification results and improve the accuracy of high-emission source identification.

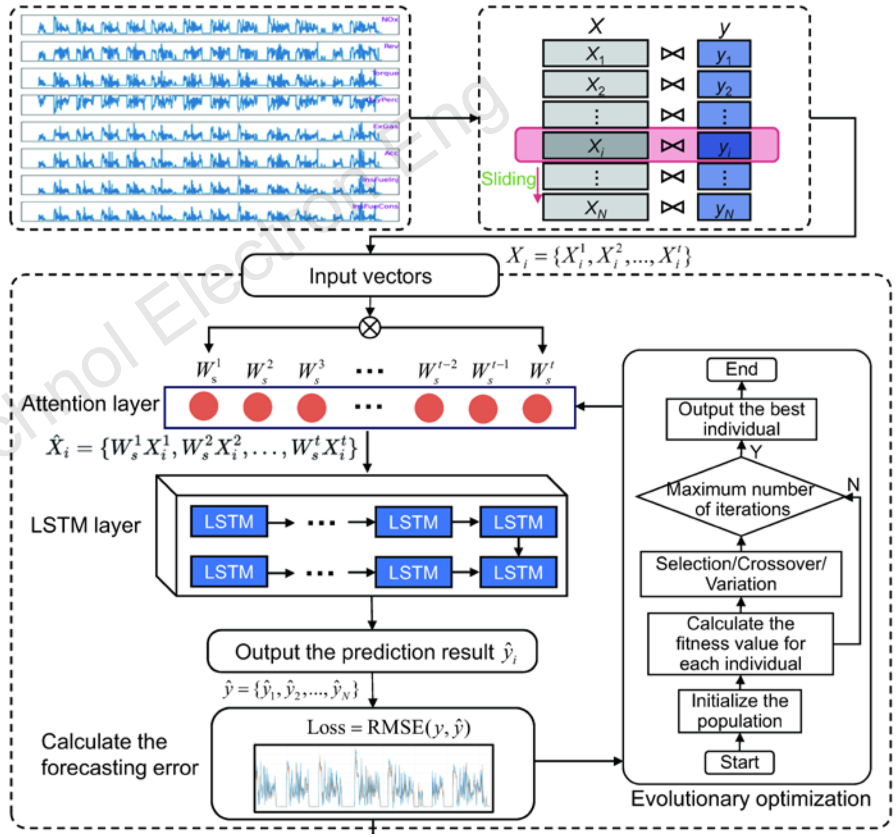
Framework



Framework of the proposed methodology: train the model for time-step attention optimization based LSTM (TSAO-LSTM) to predict the error sequence; identify anomaly emission with the unsupervised threshold; correct pseudo anomaly emission

Method

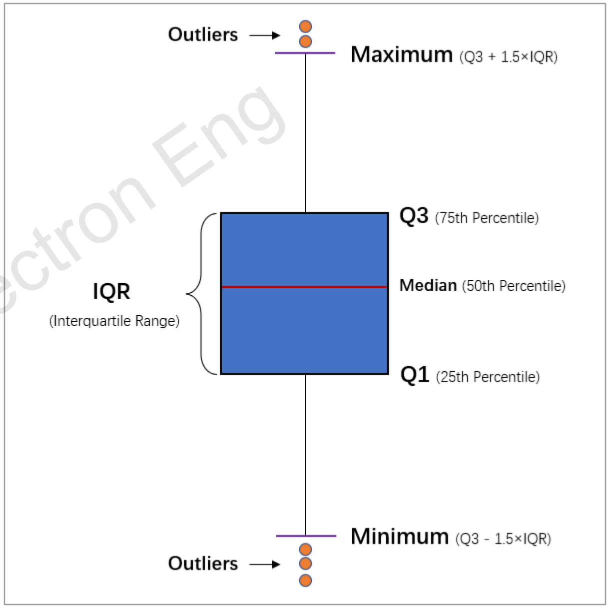
1. TSAO-LSTM is trained using normal on-board diagnostic device (OBD) time-series data to predict the test dataset. The sequence of prediction errors for emission concentration is calculated between the true and predicted values.

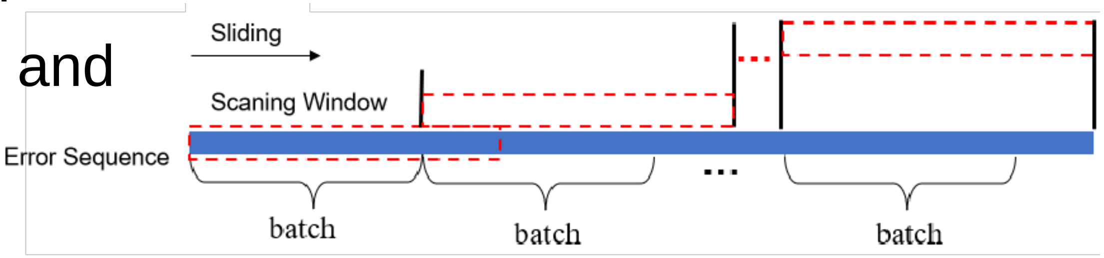


Predict the emission concentration and produce error sequences

Method

2. The scanning window slides on the segmented sequence of prediction errors, and the current unsupervised anomaly emission threshold is calculated accordingly. Specifically, contexts below and above the threshold are classified as normal and abnormal (including pseudo and true abnormal) emissions, respectively.

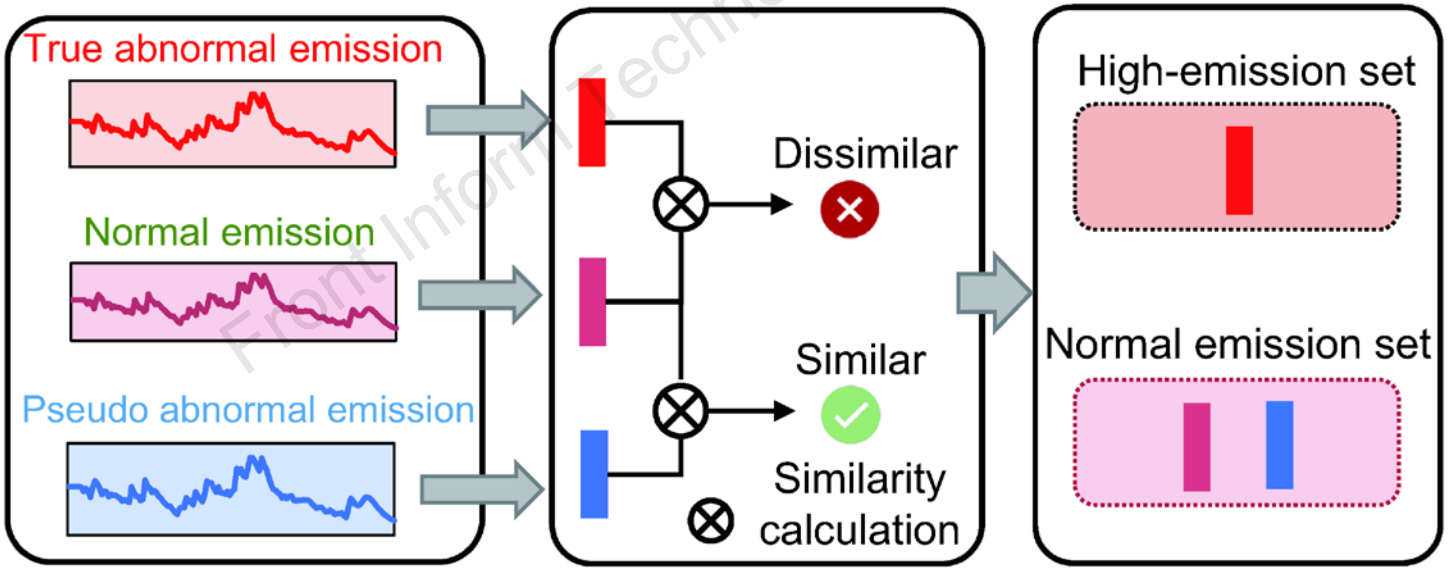




Identify anomaly emission with the unsupervised threshold

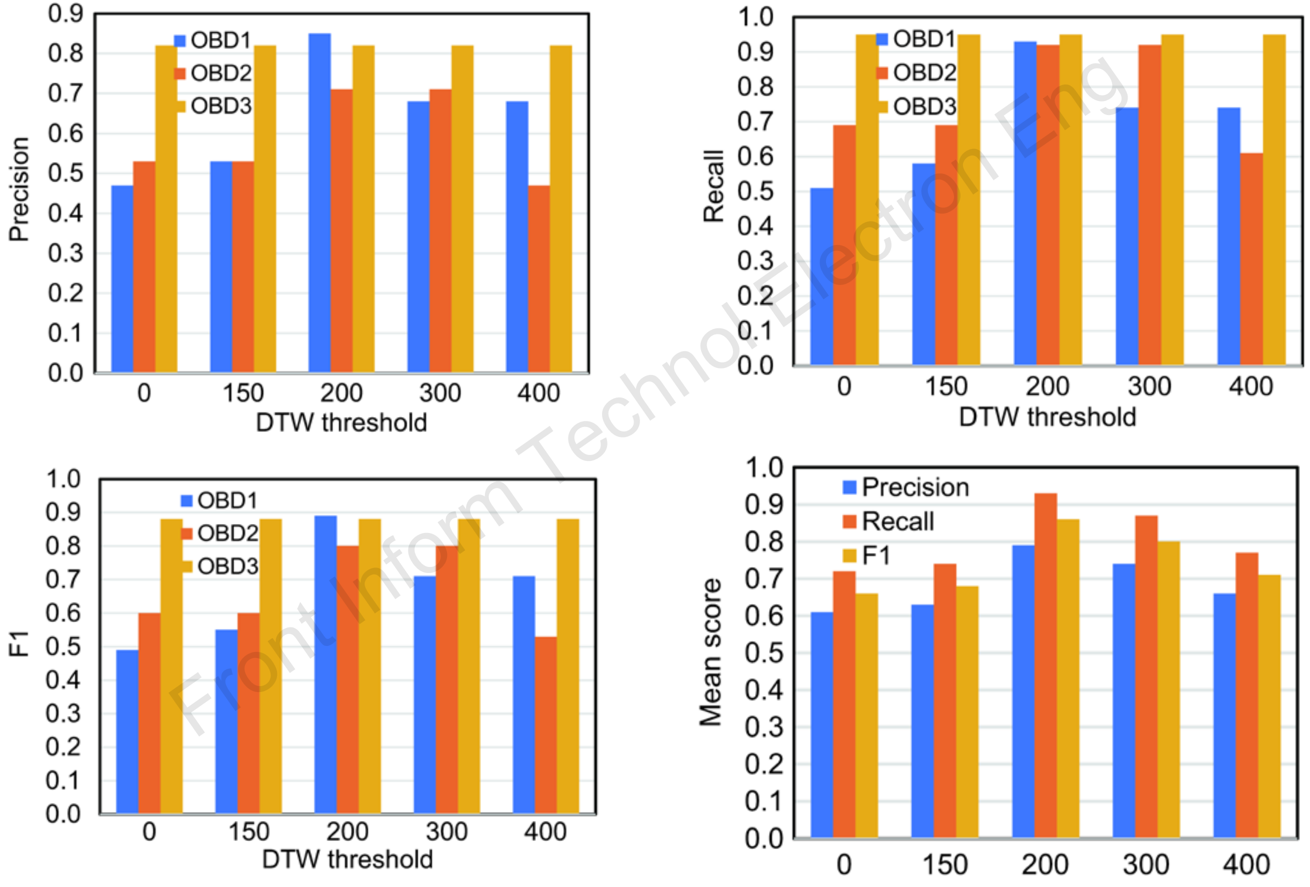
Method

3. Similarity calculations are performed in normal and abnormal emissions. If the similarity is high, the pseudo-abnormal emission is corrected and reclassified to the normal emission set; if the similarity is low, the abnormal emission is classified to the high-emission set.



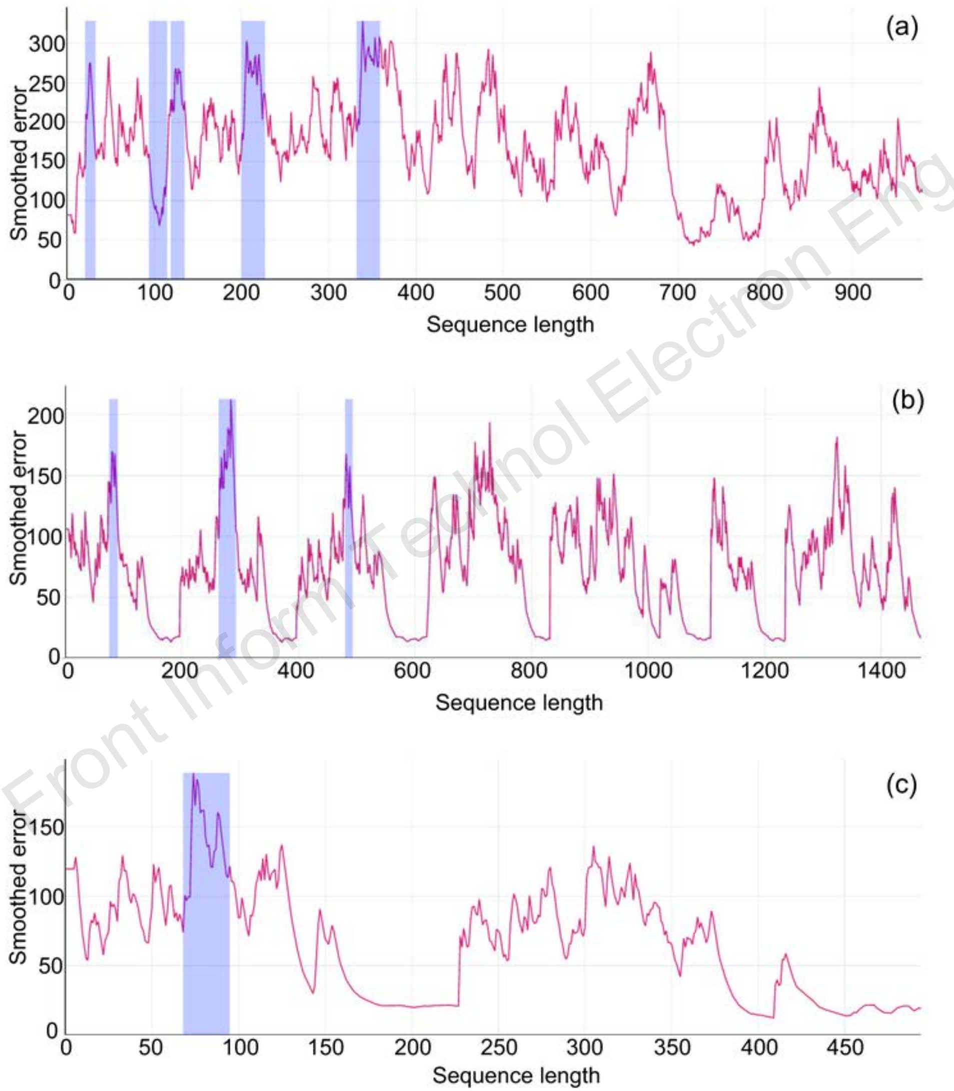
Correct pseudo anomaly emission

Major results



Evaluation of different dynamic time warping (DTW) thresholds

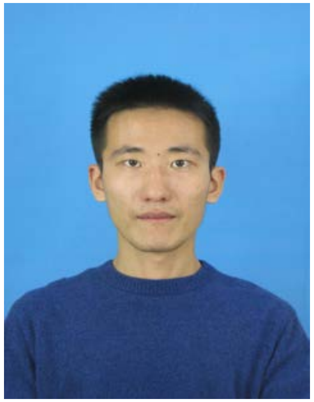
Major results



Anomaly identification on the number of emission sequences

Conclusions

- An unsupervised dynamic threshold discrimination method based on time-series prediction has been proposed for accurate detection and identification of high-emission vehicles.
- By establishing driving conditions in continuous time periods, we formulate vehicle emission identification as a time-series anomaly detection problem.
- Experiments on the Hefei mobile source OBD dataset show that our proposed method is highly accurate in high-emission identification.



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