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Machine Learning-Based Eco-Driving Level Evaluation System for Electric Bus Stop Entry and Exit Analysis

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ABSTRACT

The rapid adoption of electric vehicles (EVs) in public transportation has created new opportunities for improving energy efficiency and sustainability. Among various operational factors, driving behavior plays a crucial role in determining energy consumption, battery lifespan, and passenger comfort. This project presents a Machine Learning (ML)-based Eco-Driving Level Evaluation System designed specifically for analyzing electric bus behavior during stop entry and exit phases. These phases are critical as they involve frequent acceleration and deceleration, significantly impacting energy usage. The proposed system integrates a user-friendly graphical interface developed using Tkinter with powerful ML algorithms such as Random Forest, Support Vector Machine (SVM), and K-Nearest Neighbors (KNN). The system allows users to load real-world datasets in CSV format, train selected ML models, and predict eco-driving levels based on input driving parameters. Key features considered for prediction include mean deceleration, peak deceleration, regenerative braking ratio, maximum jerk, acceleration variance, and energy consumption per departure. The workflow begins with dataset loading and preprocessing, followed by splitting the data into training and testing sets. The selected model is trained using historical driving data and evaluated based on accuracy metrics. Once trained, the system enables real-time prediction of eco-driving levels by taking manual inputs from users. The predicted output is categorized into five levels ranging from aggressive driving to excellent eco-driving behavior, providing meaningful insights into driver performance.

The system's GUI enhances usability by offering options for model selection, dataset upload, training, and prediction in a visually intuitive manner. Additionally, full-screen functionality improves user experience during demonstrations or academic presentations. This project contributes to sustainable transportation by promoting energy-efficient driving practices through data-driven insights. It can be used by transport authorities, fleet managers, and researchers to monitor and improve driving behavior, ultimately reducing energy consumption and environmental impact. The modular architecture also allows for future enhancements such as real-time sensor integration, cloud deployment, and advanced deep learning techniques. Overall, the proposed system demonstrates the effectiveness of machine learning in evaluating and improving eco-driving behavior in electric public transport systems, making it a valuable tool for smart mobility solutions.

Keywords: Eco-Driving, Machine Learning, Random Forest, SVM, KNN, Electric Vehicles, Driving Behavior Analysis, Sustainable Transportation, Predictive Modeling, Smart Mobility

I. INTRODUCTION

The increasing global emphasis on sustainable development has accelerated the transition from conventional fuel-based vehicles to electric vehicles (EVs), particularly in public transportation systems. Electric buses are emerging as a promising solution for reducing greenhouse gas emissions, minimizing noise pollution, and improving urban air quality. However, despite their environmental advantages, the operational efficiency of electric buses heavily depends on driving behavior, especially during critical phases such as stop entry and exit. Eco-driving refers to a set of driving practices aimed at optimizing fuel or energy consumption while reducing environmental impact. In the context of electric buses, eco-driving plays a vital role in extending battery life, improving energy efficiency, and enhancing passenger comfort. Factors such as smooth acceleration, controlled deceleration, and efficient use of regenerative braking significantly influence overall vehicle performance. Traditional methods of evaluating driving behavior often rely on manual observation or rule-based systems, which are limited in accuracy and scalability. With advancements in artificial intelligence and machine learning, it has become possible to analyze complex driving patterns and predict behavior with high precision. Machine learning algorithms can process large volumes of driving data, identify hidden patterns, and provide intelligent predictions that support decision-making.

This project introduces a Machine Learning-Based Eco-Driving Level Evaluation System that leverages data-driven techniques to assess driver performance in electric buses. The system focuses on analyzing key driving parameters such as mean deceleration, peak deceleration, regenerative braking efficiency, jerk (rate of change of acceleration), acceleration variance, and energy consumption during departure. These parameters are critical indicators of driving efficiency and comfort. The system is designed with a graphical user interface (GUI) using Tkinter, enabling users to interact with the application easily. Users can upload datasets, select machine learning models, train the system, and perform predictions in a seamless workflow. The inclusion of multiple algorithms—Random Forest, Support Vector Machine (SVM), and K-Nearest Neighbors (KNN)—allows comparative analysis and flexibility in model selection. By categorizing driving behavior into different eco-levels, the system provides actionable insights for drivers and fleet operators. These insights can be used for driver training, performance monitoring, and optimization of energy consumption. Furthermore, the system can serve as a foundation for advanced smart transportation solutions, including real-time monitoring and autonomous vehicle systems. In conclusion, this project highlights the importance of integrating machine learning techniques into transportation systems to promote eco-friendly driving practices. It not only enhances operational efficiency but also contributes to the broader goal of sustainable urban mobility.

II. LITERATURE SURVEY (WITH EXISTING METHODS)

The evaluation of driving behavior and its impact on energy efficiency has been a significant research area in intelligent transportation systems. Several studies have explored various approaches, including rule-based systems, statistical analysis, and machine learning techniques, to assess and improve eco-driving performance. Early research primarily relied on rule-based models, where predefined thresholds were used to classify driving behavior. For example, acceleration and braking patterns were analyzed using fixed limits to determine whether a driver was aggressive or efficient. While these methods are simple to implement, they lack adaptability and fail to capture complex driving patterns. With the advancement of data analytics, statistical models such as regression analysis were introduced to estimate fuel consumption and driving efficiency. These models provided better accuracy compared to rule-based systems but were still limited in handling nonlinear relationships between variables. The emergence of machine learning has significantly improved the analysis of driving behavior. Algorithms such as Decision Trees and Random Forests have been widely used due to their ability to handle high-dimensional data and provide interpretable results. Random Forest, in particular, has shown high accuracy in predicting driving patterns by combining multiple decision trees and reducing overfitting.

Support Vector Machines (SVM) have also been applied in driving behavior classification. SVM is effective in handling complex classification problems by finding optimal hyperplanes that separate different classes. It performs well in high-dimensional spaces and is robust against noise, making it suitable for driving data analysis. K-Nearest Neighbors (KNN) is another popular algorithm used for behavior classification. It is a simple yet effective method that classifies data points based on their proximity to neighboring points. Although KNN is easy to implement, it can be computationally expensive for large datasets. Recent studies have also explored deep learning techniques, such as neural networks and recurrent neural networks (RNNs), for analyzing driving behavior. These models can capture temporal dependencies in driving data, making them suitable for real-time applications. However, they require large datasets and high computational resources. In the context of electric vehicles, research has focused on optimizing energy consumption through eco-driving strategies. Studies have shown that smooth acceleration, controlled braking, and efficient use of regenerative braking can significantly reduce energy consumption and extend battery life. Despite these advancements, many existing systems lack user-friendly interfaces and real-time prediction capabilities. This gap highlights the need for integrated systems that combine machine learning algorithms with interactive interfaces for practical applications. The proposed system addresses these limitations by integrating multiple machine learning models with a graphical user interface, enabling easy interaction and real-time predictions. It provides a comprehensive solution for evaluating eco-driving behavior in electric buses, contributing to the advancement of intelligent transportation systems.

EXISTING SYSTEM

Existing systems for evaluating driving behavior in transportation primarily rely on traditional and semi-automated approaches. These methods include manual monitoring, rule-based systems, and basic statistical models. While they provide a foundational understanding of driving patterns, they suffer from several limitations in terms of accuracy, scalability, and adaptability. Manual evaluation methods involve human observation or post-trip analysis of driving data. These approaches are time-consuming, subjective, and prone to human error. They are not suitable for large-scale deployment, especially in public transportation systems where multiple vehicles and drivers need to be monitored simultaneously. Rule-based systems use predefined thresholds for parameters such as speed, acceleration, and braking to classify driving behavior. For example, sudden braking or high acceleration may be labeled as aggressive driving. Although these systems are easy to implement, they lack flexibility and cannot adapt to varying driving conditions or individual driver styles. They also fail to capture complex relationships between multiple driving parameters. Statistical models, such as linear regression, have been used to estimate fuel consumption and efficiency.

While they provide better accuracy than rule-based methods, they are limited in handling nonlinear data and interactions between variables. This reduces their effectiveness in real-world scenarios where driving behavior is influenced by multiple dynamic factors. Furthermore, most existing systems lack user-friendly interfaces, making them difficult to use for non-technical users. They often require specialized tools and expertise for data analysis and interpretation. Additionally, real-time prediction capabilities are rarely integrated, limiting their usefulness in practical applications. In summary, existing systems are constrained by limited accuracy, lack of adaptability, and poor user interaction. These limitations highlight the need for advanced, data-driven solutions that leverage machine learning and provide intuitive interfaces for efficient eco-driving evaluation.

III. PROPOSED METHOD

The proposed system introduces a Machine Learning-based Eco-Driving Level Evaluation framework designed to analyze and classify driving behavior in electric buses during stop entry and exit phases. Unlike traditional rule-based or manual systems, this approach leverages data-driven models to provide accurate, adaptive, and scalable evaluation of driving efficiency. The system utilizes supervised machine learning algorithms, including Random Forest, Support Vector Machine (SVM), and K-Nearest Neighbors (KNN), to predict eco-driving levels based on key driving parameters. These parameters—mean deceleration, peak deceleration, regenerative braking ratio, maximum jerk, acceleration variance, and energy consumption per departure—are carefully selected as they directly influence energy efficiency and passenger comfort. The workflow begins with dataset acquisition and preprocessing, where relevant features are extracted and cleaned. The dataset is then split into training and testing subsets to ensure model generalization. The user can select a preferred algorithm through a graphical interface, enabling flexibility and comparative analysis. Once trained, the model predicts eco-driving levels categorized into five classes, ranging from aggressive to excellent driving behavior. A user-friendly Graphical User Interface (GUI) built using Tkinter enhances usability by allowing users to upload datasets, train models, and input real-time data for predictions. The system also displays model accuracy, providing transparency and performance evaluation.

The proposed system is designed with scalability and extensibility in mind. It can be integrated with real-time sensors, IoT devices, and cloud platforms for live monitoring and analytics. Additionally, the modular design allows for the incorporation of advanced techniques such as deep learning and reinforcement learning, which have shown significant improvements in eco-driving optimization. Overall, this system offers a practical and efficient solution for promoting eco-friendly driving behavior, reducing energy consumption, and supporting sustainable transportation systems.

IV. IMPLEMENTATION

The implementation of the Eco-Driving Evaluation System is carried out using Python, integrating machine learning libraries and a graphical user interface framework. The system is designed to be modular, interactive, and efficient, enabling users to perform end-to-end operations from dataset loading to prediction. The front-end interface is developed using the Tkinter library, which provides a simple yet effective GUI environment. The interface includes components such as buttons, labels, dropdown menus, and text fields to facilitate user interaction. Users can load datasets in CSV format through a file dialog, which is then processed using the Pandas library. Pandas enables efficient handling of structured data, including reading, cleaning, and feature extraction. Once the dataset is loaded, the system extracts relevant features and target variables. The selected features include driving parameters that significantly impact energy consumption and driving smoothness. The dataset is split into training and testing sets using the train_test_split function from Scikit-learn, ensuring that the model is evaluated on unseen data.

The system supports three machine learning algorithms: Random Forest, Support Vector Machine (SVM), and K-Nearest Neighbors (KNN). Based on user selection, the corresponding model is instantiated and trained using the training dataset. Random Forest is particularly effective due to its ensemble learning approach, which reduces overfitting and improves accuracy. SVM is used for its ability to handle complex classification boundaries, while KNN provides a simple distance-based classification method. After training, the model is evaluated using accuracy metrics, calculated through the accuracy_score function. The result is displayed on the GUI, providing immediate feedback to the user. The trained model is stored globally, allowing it to be reused for prediction without retraining. For prediction, the user manually inputs driving parameters through the GUI. These inputs are converted into numerical format and passed to the trained model, which outputs the predicted eco-driving level. The system maps the predicted label to a descriptive category, enhancing interpretability. Error handling mechanisms are implemented to ensure robustness, including validation of user inputs and exception handling during dataset loading and model training. Additionally, the system includes full-screen functionality for improved usability during presentations. The implementation aligns with modern research trends, where machine learning is increasingly applied to optimize energy efficiency in transportation systems. The modular architecture ensures that the system can be extended to include real-time data processing, cloud integration, and advanced AI models in future developments.

V. ALGORITHMS

The proposed system employs three supervised machine learning algorithms: Random Forest, Support Vector Machine (SVM), and K-Nearest Neighbors (KNN), each contributing uniquely to the classification of eco-driving levels.

Random Forest Algorithm:
Random Forest is an ensemble learning technique that constructs multiple decision trees during training and outputs the majority class for classification tasks. It is highly effective in handling large datasets with multiple features and reduces overfitting by averaging multiple decision trees. This algorithm is particularly suitable for eco-driving analysis due to its ability to capture nonlinear relationships between driving parameters.

Support Vector Machine (SVM):
SVM is a powerful classification algorithm that identifies an optimal hyperplane to separate data points into different classes. It is highly effective in high-dimensional spaces and can handle both linear and nonlinear classification problems using kernel functions. In eco-driving systems, SVM helps in accurately distinguishing between different driving behavior patterns.

K-Nearest Neighbors (KNN):
KNN is a simple yet effective algorithm that classifies data points based on their proximity to neighboring points. It calculates the distance between the input data and existing data points and assigns the class based on the majority of nearest neighbors. Although computationally intensive for large datasets, KNN is useful for capturing local patterns in driving behavior.

These algorithms are widely used in intelligent transportation systems for behavior classification and energy optimization. Recent studies have demonstrated that machine learning models significantly improve eco-driving predictions by analyzing complex driving patterns and environmental conditions.

VI. SYSTEM DESIGN

The system design of the Eco-Driving Evaluation System follows a modular and layered architecture to ensure flexibility, scalability, and ease of implementation. The design consists of four main components: Data Layer, Processing Layer, Machine Learning Layer, and Presentation Layer.

1. Data Layer:
This layer is responsible for data acquisition and storage. The system accepts input datasets in CSV format, which contain driving parameters and corresponding eco-driving levels. The data is loaded using Pandas and undergoes preprocessing steps such as handling missing values, normalization, and feature selection. Proper data management ensures accurate model training and prediction.

2. Processing Layer:
The processing layer handles data transformation and preparation. It separates features and target variables and splits the dataset into training and testing subsets. This layer ensures that the data is structured correctly before being passed to the machine learning models.

3. Machine Learning Layer:
This is the core component of the system, where the selected algorithm is trained and evaluated. The system supports multiple models, allowing users to choose the most suitable algorithm. The trained model is stored and reused for predictions, improving efficiency. The evaluation metrics, such as accuracy, are computed in this layer and passed to the presentation layer.

Modern research highlights the importance of integrating AI models into transportation systems for optimizing energy consumption and improving efficiency . This system aligns with such advancements by incorporating machine learning into driving behavior analysis.

4. Presentation Layer (GUI):
The presentation layer is implemented using Tkinter, providing an interactive interface for users. It includes functionalities such as dataset loading, model selection, training, prediction, and result display. The GUI ensures that the system is accessible to both technical and non-technical users.

Workflow:

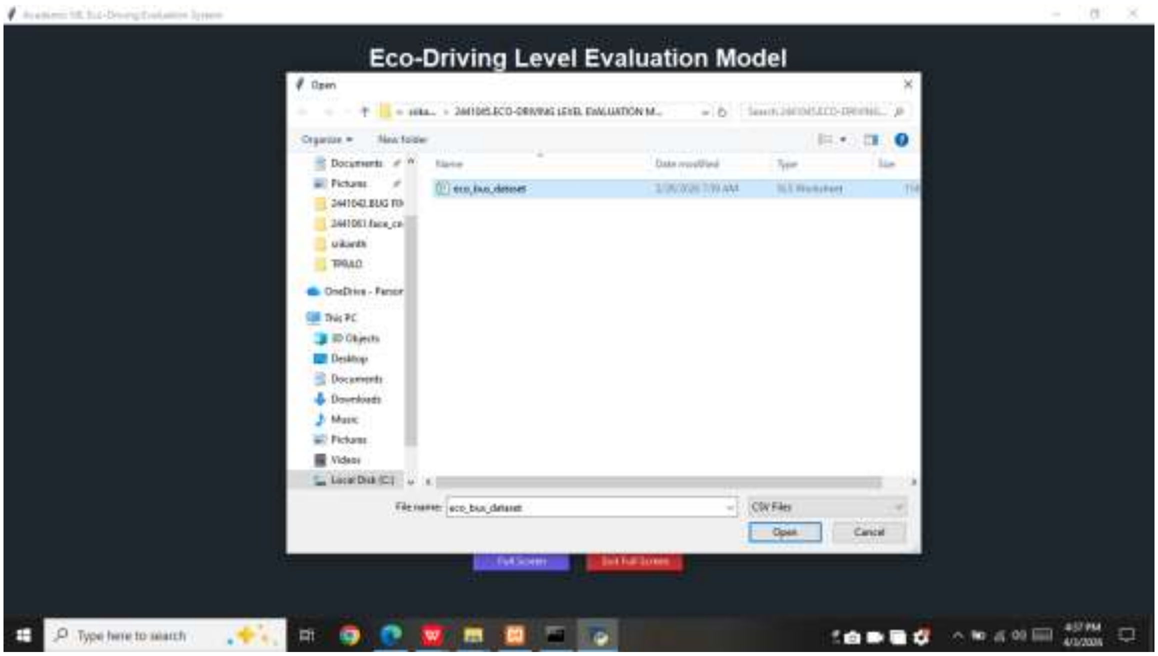
1. User loads dataset
2. System preprocesses data
3. User selects ML model
4. Model is trained and evaluated
5. User inputs new data
6. System predicts eco-driving level

Design Advantages:

- Modular and extensible architecture
- User-friendly interface
- Support for multiple ML models
- Real-time prediction capability

The system design ensures efficient data flow and interaction between components, making it suitable for academic and real-world applications.

SYSTEM DESIGN IMAGES



VII. CONCLUSION

The Machine Learning-Based Eco-Driving Evaluation System presents an effective solution for analyzing and improving driving behavior in electric buses. By leveraging advanced machine learning algorithms, the system provides accurate predictions of eco-driving levels based on key driving parameters. This enables better decision-making for drivers, fleet managers, and transportation authorities. The integration of Random Forest, Support Vector Machine, and K-Nearest Neighbors ensures flexibility and robustness in classification tasks. The system's graphical user interface enhances usability, allowing users to easily interact with the application without requiring extensive technical knowledge. One of the key strengths of the system is its ability to analyze complex driving patterns and provide actionable insights. This contributes to improved energy efficiency, reduced environmental impact, and enhanced passenger comfort. The system also aligns with current research trends, where AI and machine learning are increasingly used to optimize transportation systems and reduce carbon emissions.

Despite its advantages, the system has certain limitations, such as reliance on static datasets and lack of real-time data integration. Future enhancements may include the incorporation of IoT sensors, real-time data processing, and deep learning techniques for improved accuracy and scalability. In conclusion, the proposed system demonstrates the potential of machine learning in promoting eco-friendly driving practices. It serves as a valuable tool for sustainable transportation and provides a strong foundation for future research and development in intelligent mobility systems.

REFERENCES

1. Jamil, U. et al. (2024). *Developing an eco-driving strategy using reinforcement learning*.
2. Yang, Y. et al. (2024). *Data-driven eco-speed optimization for autonomous vehicles*.
3. Boudmen, K. et al. (2024). *Electric vehicles powered by machine learning: A review*.
4. Shi, X. et al. (2024). *Learning eco-driving strategies from human trajectories*.
5. Ren, X. et al. (2023). *Eco-driving strategies for connected EVs at intersections*.
6. Ma, Z. et al. (2024). *AI methods for energy-efficient driving behavior*.
7. Gao, K. et al. (2024). *Eco-driving optimization in intelligent vehicles*.
8. Ding, C. et al. (2024). *Deep learning systems in transportation networks*.
9. Research on hybrid eco-driving frameworks (2024).
10. Web3-based eco-driving optimization (2024).
11. Multi-agent reinforcement learning eco-driving (2025).
12. Hybrid AI for green transportation (2023).
13. Environment classification for eco-driving (2022).
14. Neural network eco-driving control (2023).
15. Data-driven predictive eco-driving control (2024).