DOI: 10.54254/2755-2721/82/2024GLG0081

Beyond Traditional Forecasting: Machine Learning and Adaptive Algorithms in EV Sales Predictions

Fei Teng

Statistics and Data Science, Rutgers University, New Brunswick, United states

ft149@scarletmail.rutgers.edu

Abstract. The Electric Vehicle market is growing fast, creating new challenges for sales predictions and market dynamics. Traditional forecasting methods like linear regression and expert judgment struggle with the market's non-linear and complex nature. To improve accuracy, new models such as machine learning and Adaptive Optimized Grey Models are being applied to predict EV sales, which is discussed in this review paper. These models dynamically adjust parameters and account for external factors, offering better precision. AOGMs, in particular, utilize data preprocessing and buffering to minimize external disturbances and enhance prediction smoothness. Techniques like the Particle Swarm Optimization help these models more effectively capture the EV sales trends. Additionally, adaptive grey models are not only essential for forecasting sales but also for identifying market risks like overcapacity or supply shortages. These advanced methods provide a more robust framework for understanding and anticipating changes in the rapidly evolving the EV market.

Keywords: Electric Vehicle, Machine Learning, Sale Prediction.

1. Introduction

Nowadays, with the growing severity of global environmental issues, energy crises, and climate change have become focal points of concern for governments and societies worldwide. As one of the key solutions to environmental problems, Electric Vehicles are viewed as an essential pillar in achieving environmental goals [1, 2]. These environmental solutions include carbon neutrality, which refers to achieving net-zero emissions over a specific period by reducing carbon emissions and increasing carbon absorption, and carbon peaking, which refers to reaching a historical peak in carbon emissions before gradually reducing them.

The country policy support, consumer interest in purchasing EVs, and accurate sales forecasts for electric vehicles are all important factors to promote the development of EVs and address environmental issues. For example, the Chinese government has introduced policies such as the "New Energy Vehicle Industry Development Plan (2021-2035)." Such policy support not only accelerates the growth of the EV market but also fosters technological advancements. Accurate forecasting plays a significant role in boosting EV sales. For policy makers, precise predictions can help design appropriate subsidies and market incentives while ensuring healthy market development. For potential car buyers, good sales forecasts can assist them in choosing the optimal time to purchase. Moreover, accurate sales forecasts are vital for automakers and related businesses, as they enable companies to adjust production plans according to market demand, optimize supply chain management, and enhance competitiveness.

Traditionally, EV sales forecasts have relied on classical statistical and financial methods. However, due to market fluctuations, these traditional methods often struggle to provide consistently satisfactory predictions. Consequently, Artificial Intelligence and Machine Learning have gradually been adopted as new forecasting tools. These new algorithms are expected to enhance prediction accuracy and adaptability, owing to their greater flexibility and learning capacity.

Meanwhile, AI and ML technologies have experienced rapid development in recent years and are now widely applied across various fields. Some representative algorithms include 1) Deep Learning, which extracts features from vast amounts of data to achieve accurate predictions and classifications, and 2) Reinforcement Learning, a technique that optimizes decision-making by allowing intelligent agents to learn through feedback from their environment. AI and ML are also being applied in diverse fields such as chemistry and material science, biology and medicine, and business analytics. In the field of electric vehicle data analysis, AI's role lies in processing multidimensional data, enabling models to better adapt to dynamic market changes and, thus, make more accurate EV sales predictions.

Previous studies have confirmed that AI can assist in producing more precise EV sales forecasts. For instance, Fatemeh Marzbani noted that emerging machine learning algorithms can process large, complex datasets and adapt to dynamic market environments, resulting in accurate EV sales predictions [3]. In Song Ding's paper, it was demonstrated that not only machine learning algorithms but also a new adaptive grey model can be used to forecast EV sales growth [4]. This grey model can adjust background or initial data according to different environments, allowing it to adapt better to various market conditions and make more precise and targeted forecasts. Similarly, in Bo Zeng's paper [5], another advantage of the adaptive model is that it uses buffer operators to process raw data affected by random disturbances based on new information, thus eliminating potential disruptions and improving forecast accuracy.

In this article, this study will first highlight the advantages of machine learning compared to traditional forecasting methods, followed by a discussion on the benefits of adaptive models, and finally, this paper will explore how adaptive models can be applied to forecast EV sales.

2. Traditional methods for EV prediction

In the process of forecasting electric vehicle sales, traditional forecasting methods were initially employed, mainly relying on linear regression analysis and expert judgment, while also being influenced by external factors. However, due to the inaccuracy often caused by these traditional methods, machine learning algorithms have gradually replaced them, providing more accurate data classification and new vehicle sales predictions. Specifically, traditional methods include:

1. Relying on past sales data to build statistical models that predict future EV trends.
2. Using regression analysis models to predict EV sales by establishing linear relationships between sales and various factors, such as price, income levels, fuel prices, and policy factors. In these regression analyses, the relationships between variables are linear.
3. Being influenced by expert judgment and external factors.

In the paper by Fatemeh Marzbani and others [3], traditional methods such as EV sales forecasting and regression analysis models require detailed parameter tuning and have a low tolerance for errors. Compared to traditional algorithms, machine learning offers several advantages:

1. Since the EV market is influenced by various complex factors, machine learning algorithms can capture these intricate and nonlinear relationships, thereby improving prediction accuracy.
2. When processing massive and multidimensional EV-related data, machine learning algorithms can classify these complex datasets without a performance drop due to the complexity of the data.
3. Machine learning algorithms can effectively achieve the desired level of accuracy and predictive performance.

In the study by Ziyun Zhao and colleagues, the main focus was on whether the massive sales of EVs could pose a potential threat to the existing power grid [6]. In their machine learning model, the EV market was divided into four major categories: private electric vehicles, electric taxis, electric buses, and government electric vehicles. Based on this classification, the model predicted whether the charging

DOI: 10.54254/2755-2721/82/2024GLG0081

load of each category would overload the grid, making the research more effective and precise. In the study by Yu-Ting Wang and others, an EV sales performance forecasting model was developed based on machine learning algorithms and Partial Least Squares methods [7]. The experimental results not only demonstrated that machine learning algorithms could effectively achieve the expected accuracy and predictive performance levels but also concluded that factors such as CO2 emissions, PM2.5 levels, the Consumer Price Index, renewable energy, and life expectancy are significantly positively correlated with EV sales.

3. Introduction of adaptive algorithms for EV prediction

In addition to machine learning algorithms, adaptive algorithms also contribute to the rapid development of EVs. Adaptive optimization models allow for adaptation to different environments and enable accurate predictions of EV growth under various conditions. The advantages of the adaptive optimized grey model are as follows:

1. In the model, the initial conditions and the reconstructed background environment enhance the model's adaptability and flexibility.
2. With data from different environments and EVs, this grey model can provide a more accurate understanding of EV development.

The adaptive optimized grey model is a method that combines grey system theory with adaptive optimization techniques to handle uncertainty and data prediction problems. The adaptive optimized grey model works by introducing adaptive optimization algorithms, such as Particle Swarm Optimization and Genetic Algorithm, to dynamically adjust the parameters of the grey model. This allows the model to better adapt to changes in the data and improve its predictive accuracy. The core idea is to continuously adjust the model's parameters through algorithms to enhance the accuracy of EV development predictions.In the study of EVs, the adaptive optimized grey model adjusts environmental parameters mainly through the following steps:

1. Input adjusted initial EV data parameters into the newly established grey model.
2. Use algorithms to continuously adjust the parameters of the grey model to minimize the fitness function.
3. Update the grey model’s parameters and use the optimized model to predict EV sales and other developments.
4. Compare the predicted results with actual values to determine if the grey model effectively predicts outcomes and whether further optimization is needed for more precise EV predictions.

In their paper, Song Ding and colleagues demonstrated that by generating a dynamic weighting sequence in the grey model experiment (to avoid missing information) [4], adjusting the weighting coefficients and initial conditions (to enhance model applicability), and using Simpson's rule to reconstruct background values (to improve predictive accuracy), they concluded from the experiment that the grey model had the highest accuracy in predicting EV sales. Optimizing the initial conditions and background values of the model significantly improved the adaptability and predictive accuracy of the grey model. Besides enhancing the model’s adaptability and predictive accuracy, the adaptive optimized grey model offers other advantages, such as real-time decision support, long-term trend prediction capabilities, and aiding resource allocation optimization, all of which contribute to the development of EVs. Real-time decision support and long-term trend prediction mean that the model not only helps businesses anticipate future market demand and EV supply, both in the short and long term, but also assists policymakers in responding quickly to market changes. For example, if the model predicts a future increase in EV demand, companies can increase supply to avoid market imbalances. Additionally, optimizing resource allocation means that the model helps businesses reduce production costs and enables consumers to avoid excessive expenses when purchasing EVs. In Qingfeng Wang’s study on forecasting the sales of electric and gasoline vehicles in China from 2022 to 2025 [8], the results showed that if China continues its supportive policies for the EV industry (Scenario 1), the EV market penetration rate in China could reach 22.45% by 2024, and by 2025, even the lowest EV penetration rate will be 20.58%. This indicates that China is likely to meet or even exceed its target for

DOI: 10.54254/2755-2721/82/2024GLG0081

increasing EV market penetration. In Kaile Zhou's research [9], under the adaptive model (i.e., the recommended model), the cost of a single electric vehicle in three public charging modes decreased by $3,548, $1,600, and $1,600, respectively.

4. The structure of adaptive algorithms for EV prediction

The adaptive optimized grey model typically has the following features: 1) dynamic parameter adjustment, 2) introduction of optimization algorithms, 3) adaptation to nonlinear trends, and 4) multi-factor forecasting. Additionally, the construction steps of the grey model include data preprocessing, AGO, establishing differential equations, and adaptive adjustments, among others. Therefore, compared to the impact of machine learning algorithms on EV sales forecasting, the advantages of the adaptive grey model lie not only in its stronger adaptability but also in its better capability to handle nonlinear trends and strong resistance to interference in systems with high uncertainty. In the study by Limin Wang and colleagues [8], the grey buffering operator was first used to preprocess the original data sequence. This helped reduce the interference of external factors (such as EV policies) on the research, and the final results indicated that data preprocessing led to more precise and reasonable prediction outcomes. Similarly, in the research conducted by Song Ding and others, the grey model applied a buffering operator based on new information to process the raw data subject to random disturbances [4], thereby eliminating potential interference and enhancing the smoothness of the system's sequence. To some extent, this also helps researchers effectively extract potential patterns in recent developments. Since the sales trend of EVs is not always linear, they employed a newly designed nonlinear grey Bernoulli model in their research, which follows the principle of prioritizing new information without data failure. Additionally, they used the Particle Swarm Optimization algorithm to determine the optimal parameters. In this context, the grey model helped them achieve more accurate prediction results, leading to the conclusion that data preprocessing is critical for forecasting new energy vehicle sales. The adaptive model not only predicts new energy vehicle sales but also accurately forecasts EV sales and inventory, allowing for the determination of whether the EV market is experiencing overcapacity or undersupply. This is crucial for ensuring the sustainable growth of EVs and promoting reasonable-scale production. In Bo Zeng's study [5], they used the small sample characteristics of China's new energy vehicle sales data to establish an adaptive optimized grey model to predict whether the EV market was undersupplied. After conducting performance tests on the model, they found that the new adaptive model outperformed other similar models in terms of overall performance. Based on this new model, the results indicated that China's new energy vehicle industry faces significant risks of overinvestment and overcapacity. Therefore, both the government and enterprises need to take appropriate measures to slow down the growth rate of EV sales and promote the healthy development of the EV market.

5. The application of adaptive algorithms for EV prediction

Because electric vehicle sales are complex and dynamically changing, adaptive forecasting models have strong data integration capabilities and can provide more comprehensive sales forecasts by introducing more covariates to reflect the complexity of the market. More importantly, the adaptive forecasting model can take into account external conditions that will affect the EV market, such as government policy support for EV development, consumer interest in EV products, and EV technology advancement and development. When these external factors are taken into account, adaptive models can better capture dynamic changes in the market, and can dynamically adjust weights and parameters based on real-time data, so that the forecast results are always in line with the latest market conditions. In Xiaosong Hu's study, singular spectrum analysis is used as a univariate time-series model. Besides, the vector autoregressive model is also used as a multivariate model. By considering the characteristics of the EV market penetration, VAR model is used to forecast the market demand of EVs. From the result of study, it could be known that VAR model considers the effect of economic indicators, including consumer price, consumer confidence, producer price, fuel and vehicle price; also the model considers the tendency of the curiosity and interest of consumers on the EV market. Therefore, VAR model is a suitable model in predicting the EV sales market. In Jinghong Yang's study [10], based on sales volume

DOI: 10.54254/2755-2721/82/2024GLG0081

of pure electric vehicles fromJanuary2020 to December 2021 have been collected, the BP neural network model is used to test the data and make a prediction of Ev Sales. By comparing the BP model prediction results with the actual sales volume, final result shows that BP neural network model could make the prediction accurate.

6. Conclusion

In conclusion, the adaptive optimized grey model has significant advantages over traditional forecasting methods in predicting electric vehicle sales. Its dynamic adaptability, ability to handle nonlinear trends, and effective resistance to external disturbances make it a powerful tool for forecasting in the complex and evolving EV market. The model's use of buffering operators and optimization algorithms like PSO enables it to provide more accurate predictions and better insights into market dynamics, such as supply-demand imbalances. Studies have shown that this model not only improves the accuracy of sales forecasts but also highlights potential risks such as overcapacity in the EV market, underscoring the importance of data preprocessing in improving prediction performance. For the sustainable growth of the EV market, both businesses and policymakers can rely on adaptive grey models to make informed decisions that balance production capacities with market demand, promoting healthy and long-term development of the EV industry.

References

[1] Sanguesa J A, Torres-Sanz V, Garrido P, Martinez F J, and Marquez-Barja J M 2021 A review on electric vehicles: Technologies and challenges Smart Cities 4(1) pp.372-404
[2] Sun X, Li Z, Wang X, and Li C 2019 Technology development of electric vehicles: A review Energies 13(1) p.90
[3] Marzbani F, Osman A H, and Hassan M S 2023 Electric vehicle energy demand prediction techniques: An in-depth and critical systematic review IEEE Access 11 pp.96242-96255
[4] Ding S, Li R, and Wu S 2021 A novel composite forecasting framework by adaptive data preprocessing and optimized nonlinear grey Bernoulli model for new energy vehicles sales Communications in Nonlinear Science and Numerical Simulation 99 p.105847
[5] Zeng B, Li H, Mao C, and Wu Y 2023 Modeling, prediction and analysis of new energy vehicle sales in China using a variable-structure grey model Expert systems with applications 213 p.118879
[6] Zheng Y, Shao Z, Zhang Y, and Jian L 2020 A systematic methodology for mid-and-long term electric vehicle charging load forecasting: The case study of Shenzhen, China Sustainable Cities and Society 56 p.102084
[7] Yeh J Y and Wang Y T 2023 A prediction model for electric vehicle sales using machine learning approaches Journal of Global Information Management (JGIM) 31(1) pp.1-21
[8] Wang Q, Liu X, and Wang L 2023 Predicting the market penetration rate of China's electric vehicles based on a Grey Buffer Operator Approach Sustainability 15(19) p.14602
[9] Zhou K, Cheng L, Lu X, and Wen L 2020 Scheduling model of electric vehicles charging considering inconvenience and dynamic electricity prices Applied Energy 276 p.115455
[10] Yang J 2023 An Analysis about the Pure Electric Vehicle Sales Prediction Based on the BP Neural Network Advances in Engineering Technology Research 7(1) pp.562-562