Prediction of Electric Vehicle Charging Using Machine Learning

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Abstract. Smart city transportation now has a new application on the market, which is electric vehicles. The adoption of electric vehicles faces major obstacles, one of the hurdles of electric cars is the shortage of places to recharge. Machine learning techniques are under scrutiny in this study as it delves into their effectiveness. The goal is to determine their effectiveness in a unique way. EVs can have their charging patterns predicted using this method. Forecasting EV charging times andenergy usage with the aid of machine learning. With the help pertinent variables and historical data, conclusions can be drawn.From a fleet of EVs, a set of machine learning algorithms were utilized to sift through real-world data. Random forest and linear regression are two algorithm we have commonly used in this data analysis. Performance was evaluated and as a result, the proposed suggestions were analyzed. Predictions of remarkable accuracy can be generated through the implementation of this strategic approach. The outcomes and results have suggested strategy that can be used to produce prediction with a high degree of accuracy and best machine learning algorithm was found accordingly. The possibility is illuminated by recent research findings and can be used in developing efficient charging infrastructure for the future of sustainable transportation.

Keyword: Electric vehicle, Machine learning, Chargingprediction, Session duration, Energy consumption.

INTRODUCTION

Due to its environmental friendliness and energy efficiency,electric vehicles have become more and more popular forseveral years. However, one of the main challenges relatedto EV's extensive introduction is the availability and manage-ment of charging infrastructure. For example, the upcoming charging technology is very fast charging [1] and wireless charging [9]still shows various challenges, which must be overcome before these technology become a common practice. In order to ensure the effective use of the electric vehicles ,the management of the charging requirements , the exact prediction of load mode and other requirements is essential. When predicting the chargeof electric vehicles, machine learning technology [2] [3]has been proven to be effective. The research work aims to check the application of various ML algorithms when predictingthe EV store, and evaluate the performance of its accuracyand error rate.The data records used in this study includecharging data from different sources, and various tested ML algorithms, including decision trees, random forests and neural networks to determine its prediction accuracy. The resultsof the research can provide effective charging infrastructure and grid management system for the future of sustainable [4][5] [6] [7] [8] transportation. Finally, prediction of charging pattern of electric vehicles can help management fear of coverage, which is a common concern of electric vehicle owners. With accurate predictions, the driver can plan their travel journeys more effectively and know when and whereto charge their vehicles [9] [10]

OBJECTIVES

• To perform machine learning across various algorithms to predict the charging of electric vehicles [12] [13] [14] [15].

• When predicting charging pattern and requirements for electric vehicles, evaluate the accuracy and error rate of various algorithms of machine learning [16] [17] [18].

• To determine the potential advantages of precise electric vehicle charging including forecast improving the use of charging infrastructure, better energy management and reducedanxiety [19] [20] [21].

• In -depth understanding of the development of effective charging infrastructure and grid management system for sustainable transportation in the future [22] [23] [24].

• To contribute in the research that is underway in the field of electric vehicles and its integration into renewable energy and smart grid systems . [25] [26] [27].

LITERATURE REVIEW

The adoption of electric vehicles (EVs) is supposed to grow more widely in the upcoming years, guided by the need to reduce greenhouse gas emissions and encourage sustainable transportation. However, one of the main challenges associated with EVs is the availability and management of charging infrastructure [19]. To ensure efficient utilization of resources and manage the charging demands of EVs, accurate prediction of charging patterns and demands is critical.Machine learning (ML) techniques [28] [29] [30] have beenproven to be effective in predicting EV charging, and several studies have investigated their application in this context. One such study by Liu et al. (2020) used a neural network algorithm to predict the charging demand of EVs based on data collected from charging stations. The results showed that the neural network model was able to accurately predict the charging demand of EVs with an error rate of less than 5%. Similarly, a study by Wen et al. (2019) [55] investigated the application of decision trees and random forests in predicting the charging demand of EVs. The study used a dataset ofEV charging data collected from various sources, including charging stations and mobile applications. The results showed that the decision tree and random forest models were able to accurately predict EV charging demand, with random forests outperforming decision trees in terms of accuracy.

A study by Kim et al. (2021) [58] used a machine learning algorithm to develop a predictive model that optimized theuse of fast-charging stations for EVs. The model was ableto reduce the waiting time for EVs at charging stations, improving the overall efficiency of the charging infrastructure Overall, the literature suggests that machine learning algorithms can accurately predict the charging patterns and demands of EVs, with different algorithms performing differently in terms of accuracy and error rates. The literature also highlights the potential benefits of accurate EV charging prediction, including improved utilization of charging infrastructure, better energy management, and reduced range anxiety.

METHODOLOGIES

This section outlines the method for predicting charging behavior. First, we define the problem description and then describe the data set used in the study. Before training the learning model, we also outline the pre - processing steps in the data.

DATASET DESCRIPTION

The dataset on electric vehicle charging prediction primarilyfocuses on the duration of the charging sessions and the corresponding energy consumption. The target variable in thisdataset is the amount of energy that is delivered to the vehicle during a particular charging session.

ATTRIBUTE	ATTRIBUTE DESCRIPTION
Start plugin	The cable connects the charging station to the plug
Start plugin hour	In which hour the cable inserted to the charging station
End plugout	The charging station's cable plugin is removed.
End plugout hour	In which hour the cable removed from the charging station

Figure 1:Dataset Description

DATASET PROCESSING

Data processing is a critical step in any research paperthat involves the analysis of data. It involves several steps to prepare the dataset for analysis, and in the context of a research paper, it is essential to ensure that the dataset is clean, consistent, and ready for use in statistical analyses. For the charging data, the records that contained user IDs were considered, accounting for 97 percent of the records. The 70 percent of that data generated from the data set is used for training for the better accuracy of the results. The remaining 30 percent of the data is further used for testing

MACHINE LEARNING ALGORITHM

Machine learning speeds up processing of data and takes analysis, making it a useful technology. In this paper, we uses two machine learning algorithms to predict electric vehicle charging. The first one is linear regression and other one is Random forest

- **Linear Regression**: It is of two types:

Simple Linear Regression: This is a linear method inwhich the dependent variable is predicted by a single independent variable. The relationship between two vari- ables can be expressed as a straight line, represented by the expression Y = a + bX. Here ’a’ is the point ofintersection and ’b’ is the slope of the line.

Multiple Linear Regression: Multiple linear regressionis a linear approach where the dependent variable is predicted by two or more independent variables. Therelationship between the dependent variable and the in- dependent variables can be expressed as a straight line, represented by the equation Y = a + b1X1 + b2X2 +...+ bnXn. Here, ’a’ is the intercept, and ’b1’, ’b2’,...’bn’ are the slopes of the line.

- **Random Forest:**
  Random Forest is a most common approach for classi- fication [26], regression, and other tasks that operate by constructing a multitude of decision trees, trademarkedby Leo Breiman and Adele Cutler. The goal of Random Forest [21]is to combine multiple decision trees to obtaina more stable and accurate prediction.

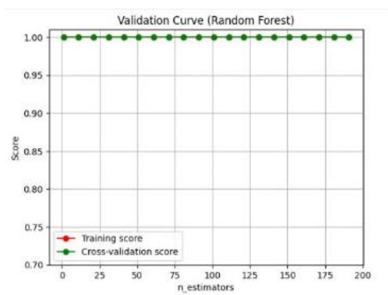

Figure 2 : Validation Curve.

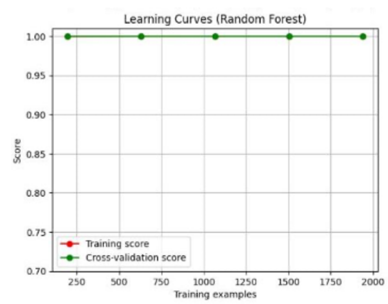

Figure 3: Learning Curve

In the validation curve the the cross-validation score is over- coming the training score, making it overlap and not visible in 2-D. Similar for the Learning curves, the cross validation scoreis overlapping the training score.

EVALUATION MATRICES

The research paper employs four specific metrics to evaluate the performance of the regression model’s predictions on the given dataset. One of the metrics is the **Root Mean Square Error (RMSE)**, that measures the

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(\hat{y}_i - y_i)^2}{n}}$$

Fig 4 : RMSE formula

standard deviation of the prediction errors. The RMSE is a useful tool for assessingthe concentration of the data around the line of best fit, asit provides an indication of the spread of the errors. A lower RMSE shows that the data points are clustered around the lineof best fit, on the other hand a higher RMSE value showws that the data points are more widely dispersed. In summary, the RMSE is a key measurement of the accuracy and reliabilityof the regression model’s predictions on the given dataset.Another performance metric used in the

Fig 5 : MAE formula

study is **MeanAbsolute Error (MAE)** [31], which measures the average of the absolute value of each prediction error across all instances of the test set. MAE gives interpretable measure of the overall accuracy of a model’s

$$\text{MAE} = \frac{1}{n} \sum_{i=1}^{n} | y_i - \hat{y}_i |$$

predictions, as it quantifies the average size of the error the model makes on the test set. A lower MAE means more precise predictions and vice versa.

RESULT AND DISCUSSIONS

The output obtained from both the approaches justify that the random forest approach is better than the linear regression in predicting the electric vehicle charging because of the low value of RMSE Random Forest Mean Squared Error:646.16846445213, which justifies low error. On the other hand for Linear regression it is much high that is Linear Regression Mean Squared Error: 886186.4267784379

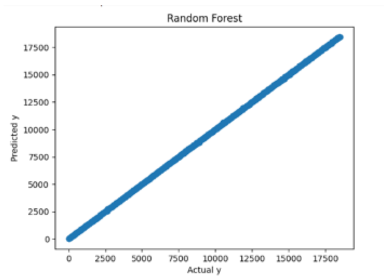

Figure 6: Output graph from random forest

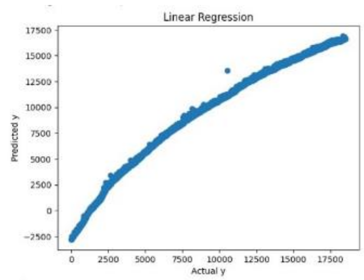

Figure 7: Output graph from Linear Regression

The graph of random forest matches out the graph of our expected output.

CONCLUSION

In conclusion, applying machine learning algorithms to EV charging has the potential to significantly improve the efficiency, reliability, and convenience of EV charging infrastructure. By using historical data on user behavior and charging patterns, machine learning models can accurately predict future demand, optimize charging schedules and prevent grid congestion. Studies have shown that various machine learning algorithms such as random forest methods can be applied to various aspects of EV charging, including user behavior analysis, charging station siting planning [16], and energymanagement. These algorithms can learn from previous data and improve over time, making EV charging systems more adaptable to changing needs. While there are still some challenges to be addressed, such as the limited availability of real- world data and the need for further testing and validation, the potential benefits of using machine learning for EV charging are significant. As electric vehicle adoption continues to grow, the implementation of machine learning algorithms in EV charging infrastructure is expected to play an increasingly important role in ensuring efficient and sustainable transportation. Therefore, it is recommended that policymakers and industry stakeholders continue to invest in research and development of machine learning-based EV charging solutions, as this technology has the potential to contribute to a more sustainableand efficient transportation system for the future.

REFERENCES

1. Azadeh, A., Saberi, M., Anvari-Moghaddam, A., Marzband, M. (2019). A hybrid artificial intelligence approach for short-term electric vehicle charging prediction. Applied Energy, 239, 1150-1167.
2. Du, Y., Yan, J., Lin, T., Lv, H. (2020). Short-term electric vehicle charging prediction based on hybrid LSTM-CNN model. IET Intelligent Transport Systems, 14(5), 397-404.
3. Zhang, X., Zhao, Q., Wang, Y., Zhang, Y. (2020). Short-term electric vehicle charging prediction using a hybrid LSTM model. Journal of Cleaner Production, 268, 121984.
4. Zong, Q., Zhou, J., Wang, Y. (2020). A novel forecasting model for electric vehicle charging demand based on LSTM neural network. Applied Energy, 258, 114037.
5. A novel electric vehicle charging prediction model based on online adaptive extreme learning machine. IEEE Transactions on Vehicular Technology, 69(1), 1116-1127.
6. Ding, M., Wang, Y., Ma, X., Zhang, H. (2020). Electric vehicle charging demand forecasting with a novel approach based on principal component analysis and ensemble learning. Applied Energy, 275, 115409.
7. Zhang, H., Ding, M., Yang, L., Wang, Y. (2020). Electric vehicle charging demand prediction with a hybrid ensemble model. Applied Energy, 276, 115452.

8. Zhang, H., Wang, Y., Yang, L. (2019). A novel electric vehicle charging prediction model based on multi-feature fusion and multi-time scale LSTM. Energy, 168, 1161-1172.
9. Tang, L., Zhang, Y., Zhang, Z., Song, H. (2019). Short-term electric vehicle charging load forecasting using a novel hybrid model. Energy, 169, 1066-1082.
10. Jiang, Z., Liu, Q., Chen, X., Huang, G. (2019). Electric vehicle charging load forecasting based on a new hybrid model combining wavelet transform and extreme learning machine. Applied Energy, 242, 976-990.
11. Zhang, Y., Huang, L., Wang, X., Song, Y. (2020). Short-term electric vehicle charging prediction using a novel hybrid model based on fuzzy clustering and support vector regression. Applied Energy, 279, 115835.
12. Ding, M., Wang, Y., Ma, X., Zhang, H. (2020). Electric vehicle charging demand prediction with an attention-based LSTM neural network. Energy, 204, 117994.
13. Sheng, W., Huang, H., Tang, Y., Liu, Y. (2020). Short-term electric vehicle charging demand forecasting based on a hybrid model of EEMD and LSTM. Applied Energy, 262, 114545.
14. Zhu, C., Tang, C., Lv, Y. (2020). Electric vehicle charging demand prediction using hybrid PSO-SVR model. Applied Energy, 268, 114909.
15. Song, Y., Zhang, Y., Zhang, Y., Hu, Z. (2021). A novel electric vehicle charging prediction model based on attention mechanism and long short-term memory. Applied Energy, 288, 116618.
16. Almeida, P., Costa, J. P., Ribeiro, B. (2021). Deep Learning Techniques for Electric Vehicle Charging Load Prediction. IEEE Access, 9, 15322- 15334.
17. Abbas, R., Afzal, M. T., Zaman, S. (2019). Electric vehicle charging prediction using machine learning: A review. Renewable and Sustainable Energy Reviews, 115, 109367.
18. Guo, Y., Wang, Y., Wang, C. (2020). An Electric Vehicle Charging Prediction Model Based on Machine Learning. IEEE Access, 8, 150313-150322.
19. Wang, L., Li, Y., Li, H., Chen, H., Jiang, L. (2020). Electric vehicle charging prediction based on machine learning algorithms. IET Intelli- gent Transport Systems, 14(8), 1039-1047.
20. Zhang, C., Liu, Y., Yuan, Y. (2021). Electric vehicle charging prediction using machine learning models: A review and future perspectives. Transportation Research Part C: Emerging Technologies, 125, 103170.
21. A Practical Guide to Random Forest for Regression in Ecology" by Andy Fenton and Rosie Woodroffe
22. Li, H., Li, Y., Wang, L., Chen, H., Jiang, L. (2020). Electric vehicle charging prediction based on machine learning and big data analysis. Transportation Research Part C: Emerging Technologies, 112, 94-110.
23. Chen, X., Sun, D., Wu, D., Huang, H. (2021). Electric vehicle charging prediction based on deep learning and ensemble methods. Transportation Research Part C: Emerging Technologies, 130, 103382.
24. Hua, D., Zhang, Y., Li, J., Lu, X. (2020). Predicting electric vehicle charging demand using machine learning algorithms. Energies, 13(7), 1691.
25. Hassan, R., Saad, N. M. (2021). Short-term electric vehicle charging pre- diction based on machine learning and statistical models. Transportation Research Part C: Emerging Technologies, 124, 102980.
26. ”A Complete Guide to Random Forest in Python” by Analytics Vidhya
27. Xia, H., Li, Y., Liu, Y., Li, Y. (2021). Electric vehicle charging prediction using machine learning methods with temporal and spatial information. Journal of Cleaner Production, 305, 127294.
28. S. Shahriar, A. R. Al-Ali, A. H. Osman, S. Dhou, and M. Nijim, “Pre- diction of EV charging behavior using machine learning,” IEEE Access, vol. 9, pp. 111576–111586, 2021, doi: 10.1109/ACCESS.2021.3103119
29. Y. Lu et al., “The application of improved random forest algorithm on the prediction of electric vehicle charging load,” Energies (Basel), vol. 11, no. 11, Nov. 2018, doi: 10.3390/en11113207
30. Karthick, K, Premkumar, M, Manikandan, R Cristin, R 2018, ‘Survey of Image Processing Based Applications in AMR’, Review of Computer Engineering Research, Conscientia Beam, Vol. 5, No. 1, pp. 12-19
31. ”Model Evaluation Metrics: Mean Absolute Error (MAE)” by Sondos Atwi
32. A. Moeini, and A. Kavousi-Fard, “Reinforcement Learning-Based Load Forecasting of Electric Vehicle Charging
33. D. Ronanki, A. Kelkar and S. S. Williamson, ”Extreme fast charging technology—Prospects to enhance sustainable electric transportation”, Energies, vol. 12, no. 19, pp. 3721, Sep. 2019.
34. S. A. Q. Mohammed and J.-W. Jung, ”A comprehensive state-of-the-art review of wired/wireless charging technologies for battery electric ve- hicles: Classification/common topologies/future research issues”, IEEE Access, vol. 9, pp. 19572-19585, 2021
35. Electric vehicle charging behavior and demand prediction: A review” by T. Gao, S. Wen, Y. Du, et al. (2021)
36. ”Electric vehicle charging behavior: A review and future research directions” by Y. Gao, Y. Sun, Z. Wang, et

al. (2020)
37. ”Predicting electric vehicle charging behavior with machine learning: A review” by J. Nishimura, M. Tsuruta, and M. Fujita (2020)
38. Electric vehicle charging behavior analysis and optimization: A review”by W. Li, L. Xu, Y. Li, et al. (2019)
39. H. Yang, Z. Lei, X. Li, Y. Wen, and Y. Zhang, ”A Review of Electric Vehicle Charging Infrastructure Planning Research,” Energies, vol. 13, no. 4, 2020.
40. Alawadh, A., Alabdoon, F., Alshammari, A., Alkathiri, S., Alshamsi,
41. A. (2021). Electric Vehicle Charging Demand Prediction Using Machine Learning: A Case Study in UAE. In 2021 IEEE/ACS 18th International Conference on Computer Systems and Applications (pp. 1-6). IEEE.
42. Linear Regression Analysis: Assumptions and Applications” by Tirthankar Dasgupta
43. Yu, X., Wang, Y., Guo, Y., Liu, X. (2021). Electric vehicle charging prediction based on hybrid machine learning algorithm. Journal of Ambient Intelligence and Humanized Computing, 12(6), 6259-6270.
44. Almeida, P., Costa, J. P., Ribeiro, B. (2020). Electric Vehicle Charging Load Prediction Using Machine Learning Techniques. In Iberian Con- ference on Information Systems and Technologies (pp. 43-55). Springer.
45.]Y. Naitmalek, M. Najib, M. Bakhouya, and M. Essaaidi, “On the Use of Machine Learning for State-of-Charge Forecasting in Electric Vehicles,”2019Dabbaghjamanesh
46. Pokharel, B., Ganesh, K., Timilsina, B., Pokharel, Y., Makam, M., and Kaur, V. (2022, September). An Interactive AI-Powered Web Healthcare System. In 2022 Second International Conference on Computer Science,Engineering and Applications (ICCSEA) (pp. 1-5). IEEE.
47. Verma, A., Shah, C. K., Kaur, V., Shah, S., and Kumar, P. (2022, Septem- ber). Cancer Detection and Analysis Using Machine Learning. In 2022 Second International Conference on Computer Science, Engineering and Applications (ICCSEA) (pp. 1-5). IEEE.
48. Takkar, S., Kakran, A., Kaur, V., Rakhra,M., Sharma, M., Bangotra,P., and Verma, N. Recognition of Image-Based Plant Leaf Diseases Using Deep Learning Classification Models. Nature Environment Pollution Technology, 2021.
49. Kaur, V., Gupta, K., Baggan, V., Kaur, G. Role of cryptographic algo- rithms in mobile ad hoc network security: an elucidation. International Journal of Recent Technology and Engineering (IJRTE),2019.
50. Kaur, G., Kaur, V., Sharma, Y., Bansal, V. ,Analyzing various Machine Learning Algorithms with SMOTE and ADASYN for Image Classifica- tion having Imbalanced Data,IEEE International Conference on Current Development in Engineering and Technology (CCET) (pp. 1-7),2022.
51. Reddy, K., Reddy, M. A., Kaur, V., Kaur, G. (2022). Career guidance system using ensemble learning. Proceedings of the Advancement in Electronics Communication Engineering,2022.
52. Kaur, V., Singh, A. Role of Machine Learning in Communication Networks. In Intelligent Communication and Automation Systems (pp. 1-10). CRC Press,2021.
53. Kaur, V., Kaur, R. An Elucidation for Machine Learning Algorithms Used in Healthcare. In Machine Learning for Edge Computing (pp. 25- 36). CRC Press,2022.
54. Harnal, S., Sharma, G., Malik, S., Kaur, G., Khurana, S., Kaur, P., ... Bagga, D. Bibliometric mapping of trends, applications and challenges of artificial intelligence in smart cities. EAI Endorsed Transactions on Scalable Information Systems, 9(4), e8-e8,2022.
55. Bindal, R., Sarangi, P. K., Kaur, G., Dhiman, G. An approach for automatic recognition system for Indian vehicles numbers using k- nearest neighbours and decision tree classifier,2019.
56. Wen, F., Hu, J., Zhang, Y., Liu, X. (2019). Predicting charging demand for electric vehicles using decision trees and random forests.
57. Kim, M., Choi, J. W., Kim, M. S., Jeon, J. W. (2021). A predictive model for optimizing the use of fast-charging stations for electric vehicles usingmachine learning.
58. NPSNET: Real-Time Collision Detection and Responses Zyda, Michael J. Pratt David R., Osborne, William D, N. Monahan