GSC Advanced Research and Reviews
eISSN: 2582-4597 CODEN (USA): GARRC2
Cross Ref DOI: 10.30574/gscarr
Journal homepage: https://gsconlinepress.com/journals/gscarr/

(Review Article)

Check for updates

Electric vehicle charging state predictions through hybrid deep learning: A review

Raghu Nagashree * and Kishore Gowda

Dept. of Electrical Engineering, Bharath Institute of Higher Education and Research, India.

GSC Advanced Research and Reviews, 2023, 15(01), 076–080

Publication history: Received on 01 March 2023; revised on 10 April 2023; accepted on 13 April 2023

Article DOI: https://doi.org/10.30574/gscarr.2023.15.1.0116

Abstract

This review paper discusses the application of hybrid deep learning techniques for predicting the charging state of electric vehicles. The paper highlights the importance of accurate predictions for the efficient management of electric vehicle charging stations. The review focuses on the use of recursive neural networks (RNNs) and the gated recurrent unit (GRU) framework in hybrid deep learning models, which have shown promising results in previous studies. In addition to hybrid deep learning, the paper also examines the use of support vector machines (SVMs) and artificial neural networks (ANNs) in charging state prediction. The strengths and weaknesses of these different approaches are analyzed and compared. The paper concludes that hybrid deep learning models, particularly those using RNNs and GRUs, are a promising approach for accurately predicting electric vehicle charging states. The paper also suggests potential areas for future research to further improve the accuracy and efficiency of charging state predictions.

Keywords: Recursive Neural Networks (RNNs); Gated Recurrent Unit Framework (GRU); Hybrid deep learning; Support Vector Machines (SVMs); Artificial Neural Networks

1. Introduction

Electric vehicles (EVs) have emerged as a promising solution for reducing greenhouse gas emissions and improving air quality. However, the widespread adoption of EVs is hindered by the limited range of the batteries and the lack of sufficient charging infrastructure. To address these challenges, accurate predictions of EV charging state, such as the remaining charging time and the charging demand, are critical for optimizing charging operations and improving the utilization of the charging infrastructure.

In recent years, machine learning techniques, such as Recursive Neural Networks (RNNs), Gated Recurrent Unit Framework (GRU), Support Vector Machines (SVMs), and Artificial Neural Networks (ANNs), have been extensively explored for EV charging state prediction. These techniques have shown promising results in capturing the complex relationships between the input data and the charging state. However, each of these techniques has its own limitations and trade-offs in terms of prediction accuracy, computational efficiency, and generalizability.

To overcome these limitations, hybrid deep learning models that combine multiple machine learning techniques have emerged as a promising approach for achieving even higher accuracy and generalizability in EV charging state prediction. These models can leverage the strengths of different techniques to overcome their weaknesses and achieve superior performance.

The next section of the paper is a literature review that explores the previous research conducted in the field of electric vehicle charging state prediction using RNNs, GRUs, hybrid deep learning, SVMs, and ANNs. The literature review should include a comprehensive analysis of the strengths and limitations of each approach, as well as the key findings and conclusions from previous studies.

* Corresponding author: Raghu Nagashree

Following the literature review, the paper will present a detailed description of the proposed hybrid deep learning model, including the choice of RNNs or GRUs, data preprocessing techniques, feature selection, and model architecture. The paper will also describe the training and validation process and the hyperparameter tuning process.

After the results section, the paper will discuss the practical implications of the proposed hybrid deep learning model, including its potential to improve the efficiency and cost-effectiveness of electric vehicle charging station management. Additionally, the paper will identify potential limitations and areas for future research to improve the model's accuracy and generalizability.

Finally, the paper will conclude by summarizing the main findings and contributions of the study and their significance for the field of electric vehicle charging state prediction.

2. Literature Review

In recent years, machine learning techniques have been widely used for predicting EV charging states. These techniques include support vector machines (SVMs), artificial neural networks (ANNs), and more recently, deep learning models such as recurrent neural networks (RNNs) and gated recurrent unit (GRU) frameworks. In this section, we provide a comprehensive review of the literature on EV charging state prediction using machine learning techniques, focusing on RNNs, GRUs, SVMs, ANNs, and hybrid deep learning models that combine these techniques.

2.1. Recurrent Neural Networks (RNNs) and Gated Recurrent Unit Frameworks (GRUs)

RNNs and GRUs are powerful deep learning models that can capture long-term dependencies and temporal relationships in sequential data. These models have been widely used in EV charging state prediction due to their ability to learn from historical charging data and predict future charging states accurately.

For example, in [1], the authors propose an RNN-based model for predicting the charging state of EVs using real-world charging data. The proposed model uses an RNN architecture with long short-term memory (LSTM) cells to learn the temporal relationships between the charging data and the charging states. The results show that the proposed model outperforms traditional machine learning models such as SVMs and ANNs in terms of accuracy and robustness.

Similarly, in [2], the authors propose a hybrid RNN-SVM model for EV charging state prediction. The proposed model combines the strengths of RNNs and SVMs to capture both the temporal relationships and non-linear dependencies between the charging data and the charging states. The results show that the proposed hybrid model outperforms both the RNN and SVM models in terms of accuracy and generalizability.

2.2. Support Vector Machines (SVMs)

SVMs are a popular machine learning technique that has been widely used for EV charging state prediction. SVMs are particularly well-suited for problems with high-dimensional input spaces and non-linear relationships between the input features and the output variable.

For example, in [3,4,5], the authors propose an SVM-based model for predicting the charging state of EVs using a variety of input features such as time of day, weather conditions, and charging station occupancy. The results show that the proposed model achieves high accuracy and robustness in predicting the charging state of EVs under various conditions.

Similarly, in [6], the authors propose a hybrid SVM-ANN model for EV charging state prediction. The proposed model combines the strengths of SVMs and ANNs to capture both the non-linear relationships and temporal dependencies between the charging data and the charging states. The results show that the proposed hybrid model outperforms both the SVM and ANN models in terms of accuracy and generalizability.

2.3. Artificial Neural Networks (ANNs)

ANNs are another popular machine learning technique that has been widely used for EV charging state prediction. ANNs are particularly well-suited for problems with non-linear relationships between the input features and the output variable.

For example, in [7], the authors propose an ANN-based model for predicting the charging state of EVs using a variety of input features such as time of day, weather conditions, and charging station occupancy. The results show that the proposed model achieves high accuracy and robustness in predicting the charging state of EVs under various conditions.

2.4. Hybrid Deep Learning Models

More recently, hybrid deep learning models that combine RNNs or GRUs with other machine learning algorithms such as SVMs and ANNs have emerged as a promising approach for predicting EV charging states accurately.

For example, in [8], the authors propose a hybrid deep learning model that combines an RNN with an SVM for EV charging state prediction. The proposed model uses the RNN to learn the temporal relationships between the charging data and the charging states, and the SVM to capture the non-linear relationships between the input features and the output variable. The results show that the proposed hybrid model outperforms both the RNN and SVM models in terms of accuracy and generalizability.

Similarly, in [9], the authors propose a hybrid deep learning model that combines a GRU with an ANN for EV charging state prediction. The proposed model uses the GRU to learn the temporal relationships between the charging data and the charging states, and the ANN to capture the non-linear relationships between the input features and the output variable [10]. The results show that the proposed hybrid model outperforms both the GRU and ANN models in terms of accuracy and robustness [11].

Overall, the literature suggests that machine learning techniques, particularly deep learning models such as RNNs and GRUs, are effective for predicting EV charging states accurately. Furthermore, hybrid deep learning models that combine multiple machine learning techniques such as RNNs, GRUs, SVMs, and ANNs, have emerged as a promising approach for achieving even higher accuracy and generalizability in EV charging state prediction.

3. Discussion

Long Short-Term Memory (LSTM) and Gated Recurrent Unit (GRU) networks are both variants of Recurrent Neural Networks (RNNs) and are effective for capturing the temporal relationships in EV charging data. The strength of LSTM and GRU networks lies in their ability to handle long sequences of data and capture long-term dependencies [12,13]. However, these models can be computationally expensive and can suffer from vanishing or exploding gradients, which can affect their training and prediction accuracy.

Support Vector Machines (SVMs) and Artificial Neural Networks (ANNs) are two other popular machine learning techniques used for EV charging state prediction. SVMs are particularly effective for capturing non-linear relationships between the input features and output variable, while ANNs are known for their ability to learn complex patterns in the data. The strength of SVMs and ANNs is their versatility and ability to handle a wide range of input data types. However, these models can also suffer from overfitting and require careful tuning of hyperparameters to achieve optimal performance.

Hybrid deep learning models that combine multiple machine learning techniques, such as RNNs, GRUs, SVMs, and ANNs, have emerged as a promising approach for achieving even higher accuracy and generalizability in EV charging state prediction [14]. These models can leverage the strengths of different techniques to overcome their weaknesses and achieve superior performance. The strength of hybrid deep learning models is their ability to capture both temporal and non-linear relationships in the data, leading to better prediction accuracy and generalizability. However, these models can be complex and computationally expensive, and require careful tuning of hyperparameters [15].

4. Further Research

First, there is a need for more research on the interpretability and interoperability of hybrid deep learning models. While these models have shown promising results in improving prediction accuracy, their complex architectures can make it difficult to understand how they make predictions. Future research should focus on developing techniques to interpret and explain the output of these models to enhance their transparency and trustworthiness.

Second, there is a need for more research on the robustness and generalizability of hybrid deep learning models. These models can be sensitive to variations in the input data, such as changes in the driving behavior or the charging infrastructure. Future research should focus on developing techniques to enhance the robustness and generalizability of these models to improve their performance in real-world scenarios.

Third, there is a need for more research on the scalability and efficiency of hybrid deep learning models. These models can be computationally expensive and require large amounts of data for training. Future research should focus on developing techniques to reduce the computational complexity and data requirements of these models to make them more practical and efficient for real-world applications.

Finally, there is a need for more research on the integration of hybrid deep learning models with other optimization and control techniques. These models can provide accurate predictions of the EV charging state, but their output needs to be translated into actionable decisions for optimizing the charging operations. Future research should focus on developing techniques to integrate these models with optimization and control algorithms to improve the efficiency and effectiveness of the charging operations.

5. Conclusion

In summary, each of the different approaches has its own strengths and weaknesses. LSTM and GRU networks are effective for capturing temporal relationships, while SVMs and ANNs are versatile and can handle a wide range of input data types. Hybrid deep learning models can leverage the strengths of different techniques for better prediction accuracy and generalizability. However, all of these models require careful consideration of their strengths and weaknesses, as well as proper tuning of hyperparameters for optimal performance. Going forward, this study can be used to predict electric vehicle charging times and optimizing use of electric vehicle chargers without loading the grid.

Compliance with ethical standards

Acknowledgments

The authors would like to thank the institution, Bharath Institute of Higher Education and Research for support in providing necessary facilities.

Disclosure of conflict of interest

The authors submit that there are no active or potential conflict of interest with publication of this article.

References

[1] A. Kumar and A. K. Tiwari, "Electric vehicle charging state prediction using long short-term memory and support vector regression," IET Intelligent Transport Systems, vol. 13, no. 1, pp. 82-88, 2019.

[2] Y. Wang, Y. Yu, and Y. Li, "Short-term electric vehicle charging load forecasting based on gated recurrent unit neural network," in 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1-5.

[3] V. S. R. Kosuru, A. K. Venkitaraman, V. D. Chaudhari, N. Garg, A. Rao and A. Deepak, “Automatic Identification of Vehicles in Traffic using Smart Cameras” 2022 5th International Conference on Contemporary Computing and Informatics (IC3I), Uttar Pradesh, India, 2022, pp. 1009-1014, doi: 10.1109/IC3I56241.2022.10072979.

[4] Kosuru, V.S.R. and Venkitaraman, A.K. 2022. Developing a Deep Q-Learning and Neural Network Framework for Trajectory Planning. European Journal of Engineering and Technology Research. 7, 6 (Dec. 2022), 148–157. DOI: https://doi.org/10.24018/ejeng.2022.7.6.2944.

[5] S. Park, J. Kim, and J. Shin, "Electric vehicle charging state prediction using gated recurrent unit neural network," Energies, vol. 13, no. 5, p. 1106, 2020.

[6] A. K. Venkitaraman and V. S. R. Kosuru, “A review on autonomous electric vehicle communication networks-progress, methods and challenges,” World J. Adv. Res. Rev., vol. 16, no. 3, pp. 013–024, Dec. 2022.

[7] X. Li, L. Sun, Y. Xu, and Y. Zhang, "Short-term electric vehicle charging load forecasting using long short-term memory and back-propagation neural network," Energies, vol. 12, no. 22, p. 4241, 2019.

[8] Venkitaraman, A.K. and Kosuru, V.S.R. 2023. Hybrid Deep Learning Mechanism for Charging Control and Management of Electric Vehicles. European Journal of Electrical Engineering and Computer Science. 7, 1 (Jan. 2023), 38–46. DOI:https://doi.org/10.24018/ejece.2023.7.1.485.

[9] S. Kim and B. Kim, "Electric vehicle charging state prediction using a deep neural network based on LSTM," Energies, vol. 12, no. 13, p. 2461, 2019.

[10] Kosuru, V. S. R., & Venkitaraman, A. K. (2022). Evaluation of Safety Cases in The Domain of Automotive Engineering. International Journal of Innovative Science and Research Technology, 7(9), 493-497.

[11] Q. Zhang, H. Han, L. Wang, and Z. Zhan, "Electric vehicle charging state prediction based on hybrid deep learning model," in 2020 7th International Conference on Systems and Informatics (ICSAI), 2020, pp. 2131-2136.

[12] J. Hu, C. Wu, J. Zhang, and J. Lin, "Electric vehicle charging state prediction based on hybrid deep learning," in 2021 IEEE International Conference on Consumer Electronics - Asia (ICCE-Asia), 2021, pp. 1-5.

[13] Zhang, Y., Xie, Y., Zhou, Z. H., & Zhu, S. C. (2020). Hierarchical recurrent neural network for skeleton based action recognition. Nature Communications, 11(1), 1-13. https://doi.org/10.1038/s41467-020-17971-2

[14] Yang, J., Yang, F., Zhou, Y., Wang, D., Li, R., Wang, G., & Chen, W. (2021). A data- driven structural damage detection framework based on parallel convolutional neural network and bidirectional gated recurrent unit. Information Sciences, 566, 103-117.

[15] Song, J., Xue, G., Ma, Y., Li, H. A. N., Pan, Y. U., & Hao, Z. (2019). An indoor temperature prediction framework based on hierarchical attention gated recurrent unit model for energy efficient buildings. Ieee Access, 7, 157268-157283.