1 Deep Learning for Battery State Prediction in Electric Vehicles: From State of Charge to State of Health

Supervisors

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Context

In the era of electric vehicles (EVs), accurately predicting battery states is crucial for both vehicle performance and user experience. Two critical battery states are the State of Charge (SOC), which represents the remaining energy available for use, and the State of Health (SOH), which reflects the long-term degradation of the battery (Luo et al., 2022).

SOC indicates the current energy level in the battery as a percentage of its total capacity, directly influencing the vehicle's remaining range and short-term driving decisions. In contrast, SOH measures how well the battery performs compared to its original state, providing insights into its degradation over time and guiding maintenance or replacement planning.

Efficient SOC prediction enables users to estimate the remaining driving range and plan recharging stops, directly influencing energy-efficient driving and short-term decisions. Moreover, this estimation, when correlated with electric vehicle usage, could play a significant role in adapting traffic control strategies to accommodate energy-efficient driving behavior and manage traffic flow based on the real-time energy states of vehicles.

This internship aims to explore **advanced deep learning techniques** for predicting the State of Charge (SOC) of EV batteries based on historical usage and operational data (Mayemba et al., 2024; Tian et al., 2023). The focus will be on utilizing sequential deep learning algorithms to process **time-series data** and on integrating recent attention mechanism architectures to enhance the accuracy and scalability of the predictions.

Once the SOC is accurately predicted, the approach could be extended to estimate the electric vehicle batteries SOH, leveraging long-term data to analyze battery degradation trends and lifespan.

The project also offers the potential for further development through a PhD opportunity, allowing for in-depth exploration and research in the field.

Objectives and Activities

The main goal of this internship is to develop a predictive model for battery health and lifespan in electric vehicles using deep learning techniques, focusing on scalability and accuracy. The following steps will guide the research:

- **Literature Review** Review state-of-the-art battery State of Charge estimation methods, focusing on data-driven approaches with deep learning, and specifically addressing challenges in time-series analysis for battery life prediction.
- **Data Preparation and Analysis** Preprocess and analyze historical battery data to identify critical parameters influencing SOC. Develop a pipeline to transform raw time-series data into a format compatible with deep learning algorithms.
- **Model Development** Implement deep learning models, such as Transformer-based architectures, to predict battery state of charge. The model will capture key dependencies in time-series data, critical for understanding battery degradation patterns.
- **Model Validation and Testing** Validate the model using real-world electric vehicles battery data and test its performance under various operating conditions. Compare its predictive accuracy with baseline approaches, adjusting hyperparameters to optimize model performance.
- **Extending to State of Health (SOH) Prediction** Explore long-cycle degradation data to model battery aging. Identify critical parameters influencing SOH (temperature, cycle frequency, discharge rates, etc.). Incorporate multi-scale modeling techniques to link SOC and SOH. For example, identify how frequent deep discharges or high-power charging (short-term behaviors) impact the battery's capacity and longevity (SOH).
- **Results Documentation and Valorization** Document the results and prepare findings for possible publication in relevant academic journals or conferences.

Materials

- Historical battery data and Electric Vehicle usage datasets
- Python programming language and libraries such as **PyTorch**
- Tools for data preprocessing and visualization, such as **Pandas** and **Matplotlib**

Candidate Profile

The ideal candidate should preferably have:

- Experience with deep learning and familiarity with sequence modeling and time-series analysis.

- Proficiency in Python programming and experience with deep learning frameworks, such as PyTorch.
- Interest in energy management, electric vehicles, and urban traffic systems.

Application Process

To apply, please send your ZIP folder named `[MobilityTransferability_NameSurname]` to `rim.slamasalmi@entpe.fr` and in copy `rochdi.trigui@univ-eiffel.fr` and `eduardo.redondo@univ-eiffel.fr` This folder should contain your **CV**, **academic transcripts** from high school (post-baccalaureate) to the most recent year of your master's program, and any **certifications in deep learning** if you have any.

References

Luo, K., Chen, X., Zheng, H., & Shi, Z. (2022). A review of deep learning approach to predicting the state of health and state of charge of lithium-ion batteries. *Journal of Energy Chemistry*, *74*, 159–173.

Mayemba, Q., Ducret, G., Li, A., Mingant, R., & Venet, P. (2024). General machine learning approaches for lithium-ion battery capacity fade compared to empirical models. *Batteries*, *10*(10), 367.

Tian, J., Chen, C., Shen, W., Sun, F., & Xiong, R. (2023). Deep learning framework for lithium-ion battery state of charge estimation: Recent advances and future perspectives. *Energy Storage Materials*, 102883.