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Regularly updated predictions of electric vehicle connection duration

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Problem definition and motivation

Electric vehicles (EVs), when charged from renewable energy sources, are a promising solution to decrease anthropogenic CO_2 emissions. The smart charging process, as a part of demand response approach, requires estimates of the charging behaviour to cope with the stochastic nature of both, the EV charging demand and renewable energy sources.

The predictions of connection duration are mostly done at the arrival of an EV to a charging station. Hence, there is potential to reach higher accuracy by updating the predictions as the charging sessions unfold.

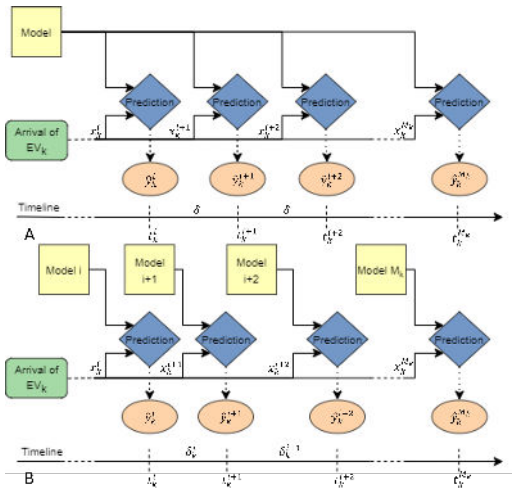
Besides practical applications, such as smart charging, the motivation is to propose novel methodology and reveal the benefit of update within the process duration predictions.

Update strategies and methods

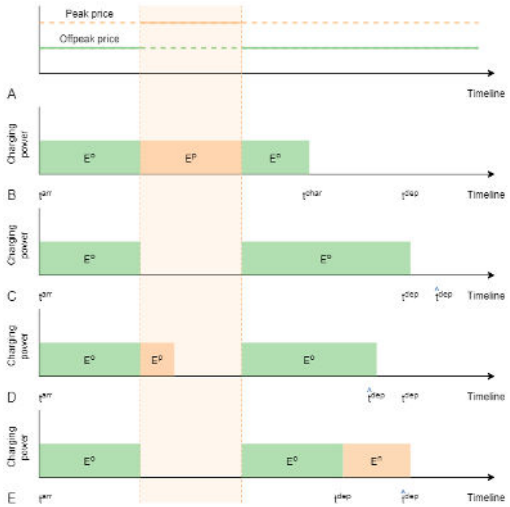
The asynchronous approach predicts for each session independently from other sessions, while the synchronous approach updates all the sessions at the same time. The thesis takes stock of the asynchronous approach using LightGBM as the prediction method which is a state of the art implementation of the Gradient Boosted Regression Trees (GBRT).

Regular and irregular updating steps strategies are deemed, as well as one prediction model for all time offsets and one prediction model for each time offset.

The most suitable values of update times for irregular update strategy are considered as the hyperparameters found by Bayesian hyperparameters' optimisation.



A: A schema of the single-model approach with regular update strategy. **B**: A schema of the multi-model approach with irregular update strategy.



Comparison of the different smart charging schemes by energy charged for offpeak price (E^o), for peak price (E^p) and demanded but uncharged energy (E^n), as the observed quantities.

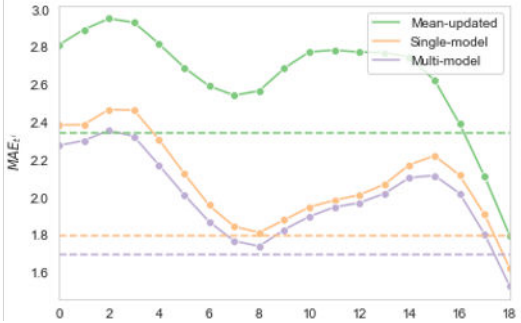
Results, contribution highlights

The multiple models with irregular updates achieve the best performance while improving the prediction accuracy up to 40%, compared to conventional approaches.

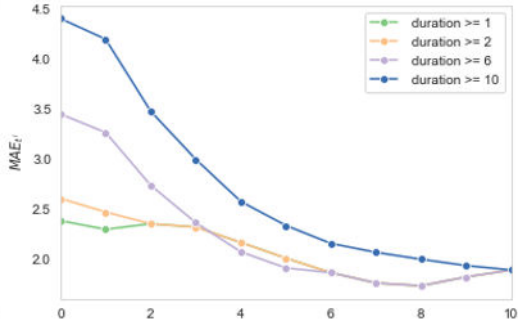
It is efficient to update the predictions with higher frequency in the very early stages of charging sessions. Later on, regular updates are sufficient.

Smart charging scheme compiled using predictions obtained by irregular update strategy:

- Mitigates the energy charged in peak-price period.
- Reaches 95.4% of energy charged in offpeak-price period in comparison with optimal charging schedule.
- Keeps uncharged energy under 3% of all demanded energy.



Accuracy, expressed by MAE, as a function of the prediction time offset t^l. Updates are made every hour. Horizontal lines indicate the value of weighted MAE .



Accuracy of the Multi-model, expressed by MAE, as a function of the prediction time offset t^l. Updates are made every hour. Only sessions lasting more than 1, 2, 6 and 10 hours are visualised.

Future outlooks and publications

In the thesis, merely the LightGBM method was used. By utilising some other methods, e.g., neural networks, some further enhancements could be achieved. Similarly, the results might be data-dependent to some degree, since we used only a single dataset.

The prediction updates should also be investigated with other characteristics of charging sessions than the connection duration.

Fundamental outcomes were published in [1] and further development, including future outlooks, is under preparation as a part of an extended paper.

[1] M. Straka, M. Jančura, N. Refa and Ľ. Buzna, "Asynchronously updated predictions of electric vehicles' connection duration to a charging station," *2022 7th International Conference on Smart and Sustainable Technologies (SpliTech)*, 2022, pp. 1-6, doi: 10.23919/SpliTech55088.2022.9854250.