Caltech cs143 Special Projects (Fall 2018): Adaptive Charging Network

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The Adaptive Charging Network (ACN) is a unique testbed on Caltech's campus which we use to explore the challenges and opportunities of large-scale, dense deployments of electric vehicle (EV) charging stations. For reference, the California parking garage currently has 54+ charging stations, all of which can be controlled and monitored through software. For more information see our recent paper [1].

The projects described here spans system design and implementation to data analysis and machine learning. Project groups that would like to work on these projects should apply to TA Zach Lee (zlee@caltech.edu). Selection will be based on your experience and enthusiasm for creating a piece of software that is useful, robust, and can be built upon by future students. Feel free to discuss with the TA Zach Lee or the instructor Steven Low (slow@caltech.edu) on more details.

Project 1: Interactive ACN Simulator

One of the efforts in our Lab has been to build a simulator based on real data for EV charging research which will make it easier for researchers to evaluate and share their algorithms. A basic event-based simulator has been developed by a SURF student. In this project you will make this simulator interactive.

Specifically, the simulator should have the following features:

- Simulator should have a graphic user interface which allows researchers to interact with the simulator in real time.
- Users should have the ability to dynamically add events to the event queue.
- Users should have the ability to step forward and backward through events in order to debug their algorithms or investigate interesting behavior.
- Users should be able to set break points in the simulation.
- When paused, the simulator should offer access to internal state variables within the network.
- While the simulator is running, the GUI should include key statistics about the network.

The following are additional features that would be great to have, but are not required.
Note that some of these features will be significantly more challenging than others. Even if you are not implementing these features, try to structure your system so that a future engineer could add them more easily.

- Users should be able to "probe" variables during a simulation, such as the charging rate of a specific charging station or the state of charge of an EV. The probed variable should be plotted for the user.
- System should display a graphic of the network complete with which stations are occupied, the congestion level of each line in the network, and the charging rate or state-of-charge of each EV.
- User should be able to specify a network through a json or XML file.

- User should be able to configure a network graphically. (HARD)
- Other ideas...

Clean code and documentation are key. If you do a good job there is a chance your code could be built upon and used by researchers around the world. This project will require extensive system design and software engineering.

Project 2: Predicting Future Arrivals

The ACN has been a valuable tool for data acquisition. We now have over 7 months of clean data from the system which includes over 10,000 charging sessions. In this project you will use this data to predict the future. Specifically you will explore if we can predict:

- when the next EV is likely to arrive;
- which parking space a newly arrived EV is likely to park in;
- when the EV will likely depart; and
- how much energy (kWh) the EV will likely draw.

Predicting these can be useful to the overall system, since if we can predict when the next EV will arrive and where it will park, we can ready the system prior to its arrival. You are free to use any machine learning or statistical modeling approach you like for this project. Since we are not sure if this is possible, you will be graded mainly based on your technique, rigor, and documentation rather than your model's performance.

The main components of the project include the following:

1. Construct from the (cleaned) raw data the spatial-temporal arrival pattern (when EVs arrive and where they park). Design input space based on available data and features that you think might be relevant.
2. Design, implement, analyze machine learning models and algorithms to predict future arrivals to the parking spaces. Test and evaluate your prediction algorithm(s) against existing data.
3. Implement online prediction and visualization system that tracks your algorithm's prediction with respect to real-time ACN data.
4. Repeat 1-3 for the other two target features, departure time and energy delivered by ACN. These two features differ from the arrival features (time and parking space) in an important way: while the arrival features depend mainly on factors external to ACN, the latter features depend also on the state of ACN and the charging algorithm implemented in ACN.

References

[1] Z. Lee, D. Chang, C. Jin, G. S. Lee, R. Lee, T. Lee, and S. H. Low. Large-scale adaptive electric vehicle charging. In *Proceedings of the IEEE SmartGridComm Conference*, Aalborg, Denmark, October 2018.