Using Machine Learning Classification to Measure Convenience of Electric Vehicle Charging Stations

Data Science Capstone - Final Project

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Introduction

This paper studies electric vehicle (EV) charging stations in California and introduces a method to evaluate the convenience of an EV charging station location. My goal is to produce a way to describe the convenience of EV charging stations, based on a machine learning classification of the number and type of nearby amenities, including: restaurants, entertainment, lodging, leisurely shopping, long-duration services, and links to other forms of park-ride transportation.

In 2018, California Governor Jerry Brown gave the State of California a goal to have 5 million electric vehicles operating by 2030. This included money to help install 250,000 charging stations in the state by 2025.[1] With this impetus for installing new charging locations, it would be useful to identify what comprises the best locations for EV charging and to help EV users find the most convenient charging stations to use, thereby encouraging EV adoption and acceptance.

I would like to help EV owners feel that it is easier to find a convenient place to charge their vehicle. The more drivers believe EV charging will be convenient, the more likely they will be to adopt EVs. I would also like to help business owners evaluate their properties for potentially providing charging stations by comparing amenities near their properties to those near known charging locations. As EV adoption increases, charging locations perceived to be convenient will likely contribute to increased customer traffic to surrounding businesses. By creating a way to describe the convenience of a charging location, I propose to help both EV users and businesses.

It has been found that EV owners perceive charging their vehicles as acceptable or unacceptable based on whether the charging activity would cause a delay in time or too much extra distance traveled away from their intended route. In other words, if a charging location is inconvenient, it is unacceptable. If no obvious acceptable charging locations are found, a person may reject the entire idea of owning an electric vehicle as impractical.[2] One way to decrease the inconvenience of charging time is by charging the vehicle while the driver is engaged in other activities, such as shopping, leisure activities, working, eating, sleeping, etc.[3]

This study makes it possible to view EV charging stations on a map and have an impression of the availability of activities which are available within a typical 1/4 mile walking distance of each station.[4] This attempts to characterize the convenience of each station based on what types of concurrent

activities it supports. Ideally, a driver would be able to choose a charging station that matches their required nearby activities. This tool would also allow a business owner to understand the amenity-based convenience of existing locations, in order to help evaluate the potential of installing new charging stations on their own properties.

Data

Location data from foursquare.com was collected for electric vehicle charging stations and nearby amenities, such as restaurants, shopping centers, etc. In addition, a list of major cities in California from the Wikipedia.com web site was used, which helped organize the initial query as well as the results.

Perceived EV charging convenience may be increased by charging a vehicle at the same time as the user is engaged in other activities, such as shopping, leisure activities, working, eating, sleeping, etc. In this study, custom lists of foursquare.com *venue categories* were created in the following classes: restaurants, entertainment, lodging, leisurely shopping, long-duration services, and links to other forms of transportation. These category classes were chosen to represent activities which typically take 30 minutes or more, and generally at least one to two hours. This amount of time was assumed to be adequate for at least a partial charge of an EV battery. Locations of people's work activities were specifically omitted, since it seems likely that EV charging options at workplaces are already being evaluated as part of employee benefits or individual arrangements.

Methodology

For a given city being analyzed, a list of charging stations and nearby amenities was collected. Nearby amenities which could usefully be visited during concurrent EV charging were collected and counted. Then, the machine learning technique of classification was applied to group stations by types and number of nearby amenities. Finally, locations of charging stations were displayed on a map, with the relative size and color of the map markers indicating the number and general types of nearby amenities. Plotting this information on a map of the city gives the user an easily understandable representation of the convenience and proximity of each charging station to particular locations of interest to the user.

In this study, for example, data was collected for EV charging stations near Los Angeles, California. 16 charging stations were listed on foursquare.com as being in or near Los Angeles. For each charging station, a list of amenities within an acceptable walking radius of 1/4 mile and which were likely to be compatible with concurrent vehicle charging of at least 30 minutes was also collected. The number of such amenities near a given EV charging station ranged from 2 to a maximum retrieval limit of 50, with a standard deviation of 17.16 (Fig. 1). The count of nearby amenities was used as a measure of convenience of the charging station, since a station with more options for concurrent activities would appear more convenient than a station with fewer options for concurrent activities.

	stationID	countAmenities
0	5c71bdc3f709c1002c848541	50
1	5c8fc732610f04002c909a18	46
2	54fcf277498e38ba3d5ec200	33
3	4f8b09d7e4b0e5ed75e8867b	50
4	51782415498ee6e7b8705246	6
5	50886290e4b0b52a6ae2ff9b	6
6	5a8f2feb6c08d17d5804a375	33
7	58d32521761b1a449bbbf466	5
8	50492ba4e4b0baed1c3c3b5b	4
9	5ac81b06535d6f631c5c0d28	42
10	5dccf2c6f94e180008a4edee	28
11	583a3de194c6904b8009c1f4	12
12	5179f614e4b027b155df66c5	13
13	526a0069498e71b4559f29ee	9
14	5420ddd9498e989575d71b79	2
15	5dd5b82c1d1198000877f2a2	27

Fig. 1. Number of nearby amenities to an EV charging station which might be compatible with concurrent EV charging

The machine learning technique of classification was then applied to group EV charging stations into similar groups based on the types of amenities available within 1/4 mile of the station. This classification provides some idea of the convenience of each group of stations, based on the types of concurrent activities desired by the user. A sample of charging stations is shown in Fig. 2, with the groups into which they were classified, as well as the top 5 most common nearby amenity categories. In this example, it is possible to guess that there would be a group of charging stations that would be the most convenient for a particular user, although there is not likely to be a group that is most convenient to all users.

	stationID	Group	1st Most Common Category	2nd Most Common Category	3rd Most Common Category	4th Most Common Category	5th Most Common Category	countAmenities
0	4f8b09d7e4b0e5ed75e8867b	4	cat_Mexican Restaurant	cat_Vietnamese Restaurant	cat_Diner	cat_Greek Restaurant	cat_Gastropub	50
1	50492ba4e4b0baed1c3c3b5b	1	cat_American Restaurant	cat_Diner	cat_Hawaiian Restaurant	cat_Greek Restaurant	cat_Gastropub	4
2	50886290e4b0b52a6ae2ff9b	1	cat_American Restaurant	cat_Diner	cat_Hawaiian Restaurant	cat_Greek Restaurant	cat_Gastropub	6
3	51782415498ee6e7b8705246	0	cat_Sushi Restaurant	cat_Vietnamese Restaurant	cat_Deli / Bodega	cat_Greek Restaurant	cat_Gastropub	6
4	5179f614e4b027b155df66c5	1	cat_American Restaurant	cat_Diner	cat_Hawaiian Restaurant	cat_Greek Restaurant	cat_Gastropub	13

Fig. 2. EV charging stations classified into numbered groups based on nearby amenities, shown with top 5 nearby amenity categories, plus a count of total nearby amenities

A map in Fig. 3 shows EV charging stations near Los Angeles, CA. Each station is visually represented by a marker with a color corresponding to the classification group of that station and a marker size based on the number of convenient amenities within 1/4 mile of the station. The map tool is interactive, allowing the user to zoom in or out of the view and click on each charging station location for more details.

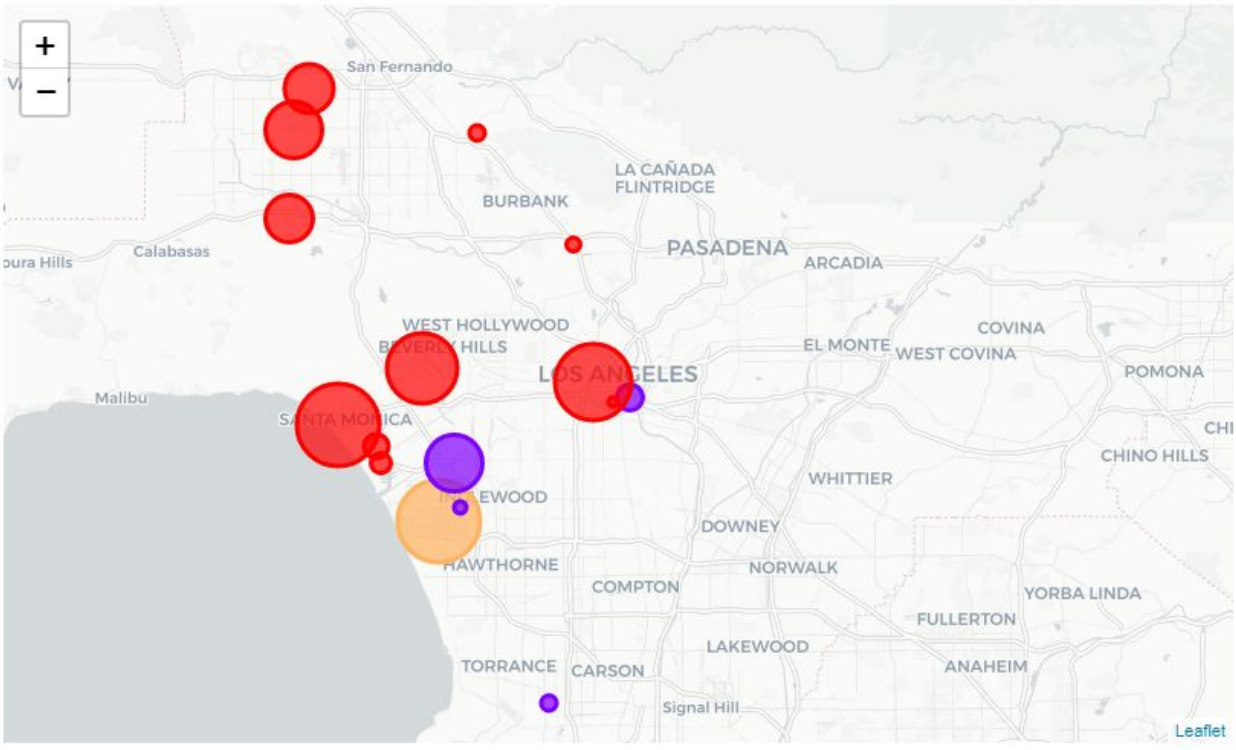

Fig. 3. Charging stations near Los Angeles, CA

Results

From an inspection of the classification results for EV charging stations near Los Angeles, CA, the classification groups appear to slightly differentiate the amenities available near each charging station. This grouping might be more useful in an area not dominated by restaurants, which were the only categories represented in the Los Angeles stations' top 5 categories. The number of nearby amenities varied far more between individual charging stations, and therefore might be more useful in describing the difference in convenience between one charging station and another.

Discussion

One limitation of the data available from foursquare.com is that all EV charging stations are listed together. Actually, there are two main types of EV charging stations, based on the rate at which they can charge an electric vehicle's battery pack. A Level 3 charging station may be able to fully charge a typical vehicle battery in 2 hours, while a Level 2 charging station may only be able to charge a typical vehicle battery 25% in 2 hours. It would be recommended to use a more detailed data source for details of charging rates of each station. In this study, it was assumed that any nearby activity which typically took 30 minutes or more was potentially a useful concurrent activity. More data on charging rates at each station may influence which nearby activities are practical in allowing a sufficient EV charge to justify the stop.

Further refinements are possible regarding which types of nearby activities would be the most convenient to a particular user. One possibility would be to provide an interface through which the user could select desirable amenity categories from a list. Stations would then be classified with respect to their proximity to these categories, resulting in a more customized determination of the relative convenience of each charging station.

Conclusion

Classification groups and number of nearby amenities seem to help describe the convenience of EV charging stations. Further, the use of a map interface seems very helpful in making the process of evaluating the convenience of charging stations easier.

It is hoped that tools such as these help users evaluate EV charging stations regarding their level of convenience and potentially feel more comfortable with the idea of EV ownership. It is also hoped that such tools will help business owners evaluate whether their properties could potentially be productive locations for EV charging stations.

References

[1] Bellan, R. (2018 October) The Grim State of Electric Vehicle Adoption in the U.S.. Retrieved from: https://www.citylab.com/transportation/2018/10/where-americas-charge-towards-electric-vehicles-stands-today/572857/

[2] Daubitz, S. & Kawgan-Kagan, I. (2015) Integrated charging infrastructure: cognitive interviews to identify preferences in charging options. *European Transport Research Review 7*(35), 1.

[3] Daubitz, S. & Kawgan-Kagan, I. (2015) Integrated charging infrastructure: cognitive interviews to identify preferences in charging options. *European Transport Research Review 7(*35), 12.

[4] Yang, Y. & Diez-Roux, A. (2012) Walking distance by trip purpose and population subgroups. *American Journal of Preventative Medicine 43*(1), 11–19.