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Research Report

Forecasting Latent Demand for Rapid Charging Station for Electric Vehicles

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Abstract

In recent years, placement problems of rapid charging stations for electric vehicles (EVs) have attracted attention for the widespread use of EVs. A latent demand forecast of the rapid charging stations is important for the placement. Here we propose an approach to forecasting this demand. A key aspect of our approach is to utilize differences between distributions of the gasoline vehicles (GVs) and the EVs for criteria of the demand. We also demonstrate usefulness of our approach through a simple embodiment with synthetic data.

1 Introduction

In order to trigger the widespread use of electric vehicles (and plug-in Hybrid Vehicles), placement problems of rapid charging stations for these vehicles have attracted much attention over years. Especially, an incremental demand forecasting of the stations, instead of a batch placement problem of the stations, will be more important since several stations have already been installed in many regions.

In this report, we propose an approach to forecasting a latent demand for the rapid charging stations with probe-car data. Our approach is based on a simple assumption that, in areas holding this demand, (probability) densities of electric vehicles (EVs) are less than densities of the gasoline vehicles (GVs), *i.e.*, one of the causes that prevents EVs from prevailing in such areas is the lack of the stations for EVs. Based on this assumption, we propose an approach to utilizing differences between distributions of the GVs and the EVs as criteria of the degree of the demand in Section 2. We also demonstrate usefulness of our approach through a specific embodiment with synthetic data in Section 3.

2 Demand forecasting of rapid charging station

2.1 Basic idea

We adopt a very realistic assumption that a cause that prevents the EVs from prevailing in an area is the lack of the rapid charging stations of the EVs (or pHVs) in the area. This assumption indicates that the area where the probability density (or number) of EVs is much less than that of the gasoline vehicles (GVs) will have a latent demand of the station. This observation is utilized in our approach to demand forecasting of the stations with probe-car data[1].

2.2 Approach

According to the above observation, we propose an approach in which the latent demand of the rapid charging station is identified on the basis of the distributions of the EVs and the GVs. These distributions (or the ratio of them) will be estimated from a large amount of probe-car data. If the density of EV in an area is estimated to be less than the density of GV in the area, the area is considered to have the latent demand for the stations in our forecasting.

As an instance, we provide a simple and concrete procedure with some remarks as follows:

(A) Extract spots (areas) which the EVs and the GVs existed in, from the probe-car data, *e.g.*, $\mathcal{EV} \triangleq \{(x_1^{\mathrm{ev}}, y_1^{\mathrm{ev}}), (x_2^{\mathrm{ev}}, y_2^{\mathrm{ev}}) \ldots, (x_m^{\mathrm{ev}}, y_m^{\mathrm{ev}})\}$ and $\mathcal{GV} \triangleq \{(x_1^{\mathrm{gv}}, y_1^{\mathrm{gv}}), \ldots, (x_n^{\mathrm{gv}}, y_n^{\mathrm{gv}})\}$.[2] $\mathcal{EV}$ and $\mathcal{GV}$ are sets of the EV's and GV's spots, respectively. x and y denote the latitude and longitude, respectively. The superscripts of x and y represent the car-type. The subscript is a kind of serial number, *i.e.*, there are m or n spots for EVs and GVs in the case, respectively.

(B) Estimate probability densities of the EVs and the GVs with $\mathcal{EV}$ and $\mathcal{GV}$, *e.g.*, $p_{\mathrm{EV}}(x, y \,|\, \mathcal{EV})$ and $p_{\mathrm{GV}}(x, y \,|\, \mathcal{GV})$, respectively.

(C) Compute a criterion for the latent demand $f(x, y)$ with $p_{\mathrm{EV}}(x, y \,|\, \mathcal{EV})$ and $p_{\mathrm{GV}}(x, y \,|\, \mathcal{GV})$. The criterion $f(x, y)$ only has to satisfy the requirement that, if $p_{\mathrm{GV}}(x, y \,|\, \mathcal{GV})$ is larger compared with $p_{\mathrm{EV}}(x, y \,|\, \mathcal{EV})$, then $f(x, y)$ is larger. Therefore there will be various definition of $f(x, y)$, *e.g.*,

$$f(x, y) := p_{\mathrm{GV}}(x, y \,|\, \mathcal{GV}) - p_{\mathrm{EV}}(x, y \,|\, \mathcal{EV}),$$

or

$$f(x, y) := p_{\mathrm{GV}}(x, y \,|\, \mathcal{GV}) \big\{ \log p_{\mathrm{GV}}(x, y \,|\, \mathcal{GV}) - \log p_{\mathrm{EV}}(x, y \,|\, \mathcal{EV}) \big\}. \quad (1)$$

[1] The probe-car data consists of a time series data of EVs and GVs with coordinates (latitude and longitude), speed, and car-Type/ID, etc. recorded at regular intervals, as an input data.

[2] Because a few minutes are at least necessary for an electric charge, regions in which vehicles often stop for a few minutes might have a higher latent demand for the rapid charging station. Thus, it would be useful for the procedure (A) to be executed under some constraints such as omitting a data that the standing time is less than t minutes.

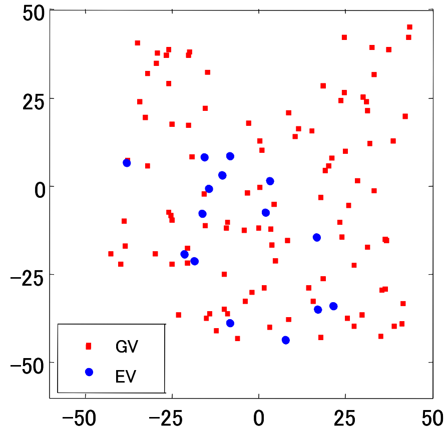

Figure 1: Scatter plot of vehicles as a result example of the procedure (A) with a probe car data.

(D) Identify areas holding the latent demand by searching the area in which the criterion $f(x, y)$ becomes larger compared with the other areas.

It is noted that, while the criterion f is evaluated through estimating p_{EV} and p_{GV} in the above procedures, a direct estimation of f from the data $\mathcal{EV}$ and $\mathcal{GV}$ will be feasible with the existing techniques such as the KLIEP [**?**], and would be preferable especially if the number of the member of $\mathcal{EV}$ or $\mathcal{GV}$ is small.

3 Simple embodiment example

Here we provide an example of our approach with a synthetic data.

Figure 1 is a scatter plot of vehicles as an example of a result by the procedure (A). This plot consists of members of the sets $\mathcal{GV}$ and $\mathcal{EV}$, respectively, which are synthesized with random variables. Figure 2 shows probability densities of the GV and the EV, which are estimated from $\mathcal{GV}$ and $\mathcal{EV}$ with Gaussian kernel density estimation with the scatter parameter $\sigma = 10$, as results by procedure (B). Figure 3 shows the latent demand criterion $f(x, y)$ of Eq. (1) as a result by procedure (C). As the procedure (D), we will identify from Figure 3 the area that has higher demand for the rapid charging station. In this embodiment example, the areas around $(x, y) = (40, 40)$ or $(-30, 35)$ would be evaluated as holding higher demands for the stations.

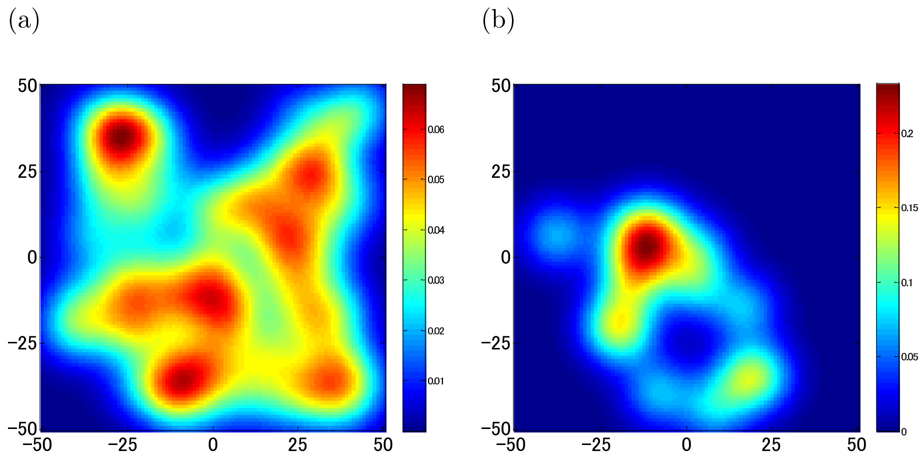

Figure 2: Estimated densities as result examples of the procedure (B): (a) the GV density $p_{\mathrm{GV}(x,y\,|\,\mathcal{GV})}$ (b) the EV density $p_{\mathrm{EV}(x,y\,|\,\mathcal{EV})}$.

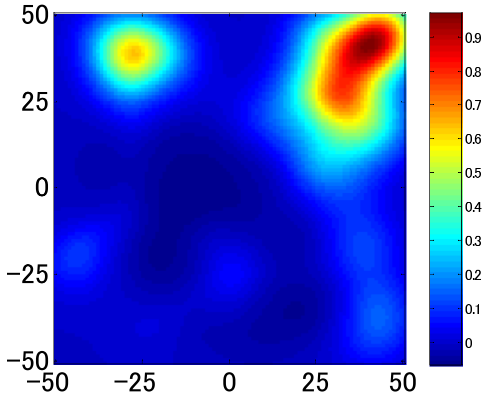

Figure 3: Estimated latent demand for the rapid charging station

4 Conclusion

We propose a framework to forecasting the latent demand for the rapid charging stations for the EVs on the basis of the distributions of the EV and GV. The key aspect of our approach is to use probability densities of a product (in our case, GV) that is similar to a targeted uncommon-product (EV) but is not uncommon, as potential abilities (or baselines) of the targeted product to become prevalent.

Obviously, our approach will be useful in other domains such as a latent demand forecast of base stations for a next generation mobile phone.