Intelligent Wireless Charging for Electric Buses in the Smart City

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Abstract

The transportation industry is amidst a technological transformation to identify and adopt alternative sources of energy to power vehicles due to environmental factors. We examine the Metropolitan Transit Authority (MTA) buses since they operate in the city on a continuous cycle with increased coverage during peak transit times. We focus on the B63 bus route and perform a feasibility study to determine primarily whether wireless charging at specifically designated bus stops throughout the city can help to increase the feasibility of electric buses for city use both from an operational standpoint.

We propose a framework that consists of a probabilistic model to capture the nature of the data and formalizing the feasibility study as an optimization problem. Using this framework we utilize the history of the system and the properties of the technology to find suitable locations for electric chargers without disrupting the operation of the system.

Goal of Study

The goal of our experiment is to demonstrate the feasibility of the technology by formalizing an optimization problem to find suitable locations for chargers and a metric to quantify the utility of an arrangement of chargers given the characteristics of the technology (i.e. battery capacity, charge, discharge rate).

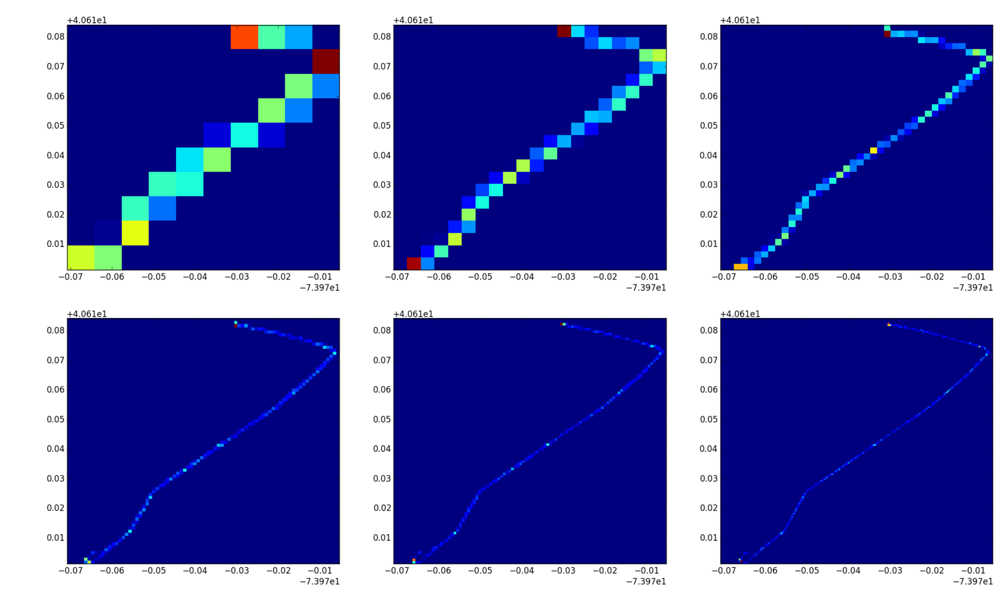
Data & Clustering

- Our data consists of periodic records with average 30 seconds time lapse from vehicles in Brooklyn B63
- Each record consists of a time stamp, and gps tag accompanied by the vehicle id that the data is recorded from and the distance to the closest stop, the id of the aforementioned stop, direction id and trip id.
- The three latter attributes are used to identify a unique trip of a vehicle from a rest stop to the last.

Preprocessing

Transform the dataset into one that can yield the most relevant insight and be of utility for the purposes of this study and beyond.

Superposition of all records in our dataset on the a map of Brooklyn.

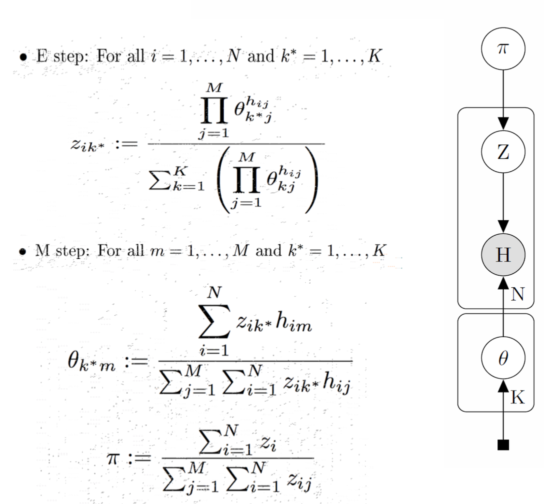


Six matrix histograms (heat maps) showing the same trip imposed upon grids of different granularity parameter *m*.

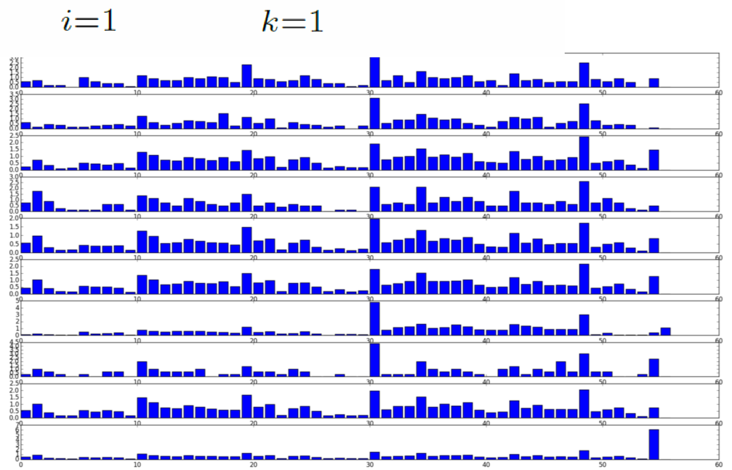
Probabilistic Model

- Multinomial mixture model as a probabilistic model in order to capture the nature of the observations.

$$p(h_{1:N}|z_{1:N},\theta_{1:K},\pi) = \prod_{i=1}^{N} p(z_i|\pi) \prod_{k=1}^{K} p(h_i|\theta_k, z_i)$$



The EM procedure describing inference (left) for the probabilistic graphical model depicted on right



The result of running an instance of multinomial mixture model with 10 clusters on our data. Each histogram shows the distribution of time spent at each bus stop. The stops appear on the histogram with the order that they appear on their physical route. The unit of time in the graphs is 30 sec.

Optimization

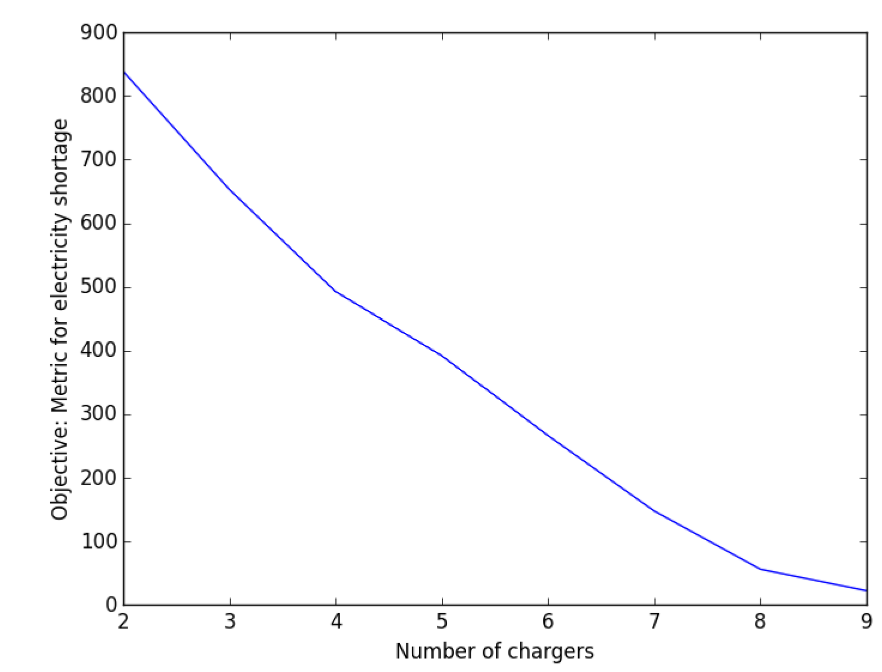
- In the optimization problem we aim to reduce the amount of down time for buses on their way based on the historical data set.
- The utility function below describes the total amount of electricity with is overdrawn from bus batteries in the historical dataset.
- Since the large amount of data points introduces much difficulty in calculating this objective function, we use the model to substitute all trips with only the cluster characteristic trips.
- σ is a solution that is a set of stops with charging pads.

$$U(\sigma) = -\sum_{i=1}^{M}\sum_{j=1}^{N} \mathbb{I}(f_{ij}(\sigma) < 0) \times f_{ij}(\sigma)$$

$$f_{ij}(\sigma) = 100 + \sum_{k=1}^{j-1} (-(\sigma_k - \sigma_{k-1})\delta + \rho h_{i\sigma_k}) - (\sigma_j - \sigma_{j-1})\delta$$

Results

Since our optimization problem is a hard combinatorial problem we us a stochastic local search algorithm (perturbing some coordinates) to find the local optimum.



Depicting the utility of the suboptimal solutions to our problem for a fixed characteristics (ρ, δ – the charging and discharge rates) for different fixed number of chargers.

CONCLUSIONS

We provide a framework that demonstrates wireless chargers can be introduced to the MTA service without disrupting the current schedule by selecting a fraction of bus stops for deploying them, based on the specific type of charging and battery technology.

Acknowledgments

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