Smart Parking in Toronto

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A. Primary questions

The main problem we would like to solve is how to help municipalities optimize parking in Toronto. It can be done by reducing parking time of the vehicles at an individual level, or by finding optimal areas to place new parking locations for commercial vehicles. We decided therefore to split the problem into two main parts, one for individual vehicles and one for general organization.

I. Individual vehicles : How do we optimize parking time?

- How do we identify free parking spots ?
- How do we decide which vehicle to place at each free parking spot, when there are several demands at the same time ?
- How to provide an optimal route for vehicles to the parking spot ?

II. General organization: Where can we place new parking facilities?

- Which are the locations the vehicles spend most time in before finding a parking spot? (this can help identify where to add more signage board)
- How's vehicle movement at different neighborhoods?
- Is there a consistently growing number of vehicles circling around for parking at a neighborhood over a period of time?
- Which are the neighborhoods in close proximity to the one with high traffic,with potential for more parking facilities?
- What kind of vehicles look for parking at a neighborhood?

B. Data Collection

I. Geotab - SearchingForParking

The dataset identifies areas within a city where drivers are experiencing difficulty searching for parking. The dataset includes cities with a population of more than 100,000. The project only focuses on City of Toronto.

We need to use query to extract data from SearchingForParking table.

Some sample SQL code:

```
import datalab.bigquery as bq
SQL = """
  select * , TotalSearching/(TotalSearching/(PercentSearching)) as SearchingForParkingRatio
  from `geotab-public-intelligence.UrbanInfrastructure.SearchingForParking`
  where TotalSearching >= 10
"""
summary = bq.Query(SQL).to_dataframe(dialect='standard')
```

II. City of Toronto - Open Data

City of Toronto (https://www.toronto.ca/city-government/data-research-maps/open-data/open-data-catalogue/) provides several open datasets on city traffic and parking. We reviewed some relevant datasets including parking tickets, parking lot facilities, green p parking and vehicle and pedestrian volumes to see whether they are helpful to answer our questions.

Dataset	**Description**	**Utility**	**Challenges**
Parking lot facilities	Provides information about parking lots operated by Parks, Forestry, and Recreation Division of the City of Toronto. This data was collected from 2013 to 2015.	Can be used to identify additional free parking spots other than on streets	They provide the GIS coordinates, so we have to convert them to geohash and match with where vehicles are parked (according to Geotab data). We also have to make sure that this data is not outdated.
Parking Ticket Data	Provides tickets issues at different localities. Localities are mostly approximated to closest street address. Provided for City of Toronto for the year of 2017, at ticket level with day and time of ticket issue.	Can be used as a proxy feature to congestion in different localities	Mapping to GeoTab geohas locations since the locations are descriptive in dataset
Traffic Signal Vehicle and Pedestrian Volume Data	Provides information for vehicle and traffic volume through streets of toronto from 2004 where there were traffic lights.Available at daily level from the date of activation and lattitude, longitude information provided	Can be used to assess growing congestion patterns across different neighborhoods. Which can be used to combined with the number of vehicles searching for parking in the location to assess how much of the traffic is due to vehicles not able to find parking spots	Mapping location lattitude and longitudes can be quite challenging
GreenP Parking	Provides information about municipal off-street parking lots ('Green P'), and the on-street metered parking. Includes information about location, rate, and capacities.	Can be used to identify on-street and municipal off-street (including 17 TTC off-street parking facilities in Toronto. Since it contains the rates, it can be used to guide the vehicles to the "cheapest" parking spots.	Json file ; again, the latitude & longitude should be converted to match the geohash information provided in the Geotab data. Should be careful when check if this data overlap with Parking lot facilities data for example.
Chapter 950 Schedule	Provides traffic and parking by-law data from 44 schedules to City of Toronto Municipal Code Chapter 950, Traffic and Parking. including "No Parking", "No Stopping", "No Standing", "Parking for Restricted Periods", "Reserved Lanes for Designated Classes of Vehicles", "Prohibited Turns", "Speed Limits"	Can be used to find the parking rules in Toronto. (know which place is no parking, which place can park in restricted time). When we give suggestion to individual drivers or predict optimized parking route, we can refer to the data	It has numerous (45) xml files to indicate parking and traffic rules in specific area or street. It may be challenging to collect information in all xml files.

On-Street Permit Parking Area Maps	Permit parking areas within the City of Toronto are presented in map format. Data can viewed in http://map.toronto.ca/maps/map.jsp?app=OpenData	Can be used in visualization to indicate each area in a map. There is a lot of information, seems only on-street permit parking area is useful for the project.	The dataset contains several files, which are extended by .dbf, .prj, .shp, .shx. Need to figure out how to visualize this data in a map.

C. Exploratory Data Analysis

In this section, we describe different visualizations/ statistical tests that we propose for a better understanding of the parking patterns of the city

I. Individual vehicles: How do we optimize parking time?

- How do we identify free parking spots?
  Proposed Approach:
  - The merged parking lot facilities, Green P Parking and On-Street parking permit areas with GeotabSearchingForParking dataset is used to identify parking slots in each GeoHash
  - Compare the total available slots to the total number of vehicles searching for parking at different points of time using a bar chart. This would give us an idea of how many free spots are available in an area. If none are available, search for the next say 3 closest geohash, based on coordinates distance
  - Plot the same on a map visualisation to indicate to the user potential zones with free parking areas

- How do we decide which vehicle to place at each free parking spot?
  Proposed Approach:
  - The merged parking lot facilities, Green P Parking and On-Street parking permit areas with GeotabSearchingForParking dataset is used to identify parking slots in each GeoHash
  - Study congestion close to the free parking spot, in geo hash. If the number of vehicles searching for parking is low then recommend this spot to the vehicle driver-> A simple likelihood score of the vehicle getting the parking spot based on time to reach spot, type of vehicle and congestion in route
  - Use a heat map visualisation to observe congestion close to free parking spots

- How to provide an optimal route for vehicles to the parking spot ?
  Proposed Approach:
  - Use Google Maps API to show routes to closest say 3 free parking spots with high likelihood of getting it for the vehicle

Figure1: An illustrative map visualisation adapted from GeoTab White, shows diff. routes taken by vehicle searching for parking in a geohash

II. General organization: Where to place new parking facilities?

- Which are the locations the vehicles spend most time in before finding a parking spot? (this can help identify where to add more signage board)
  Proposed Approach:
  - A bar plot of the avg. parking time and number of parking issues across each geohash location

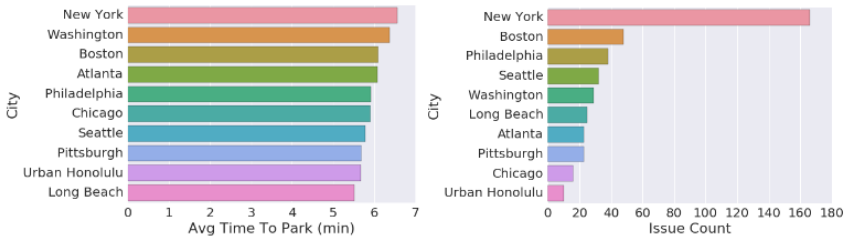

Figure 2: An illustrative chart adapted from GeoTab White paper on searching for parking

  - A bar plot of the avg. parking time ratio across each geohash location
  - A map showing heat zones in the city with high avg. parking time

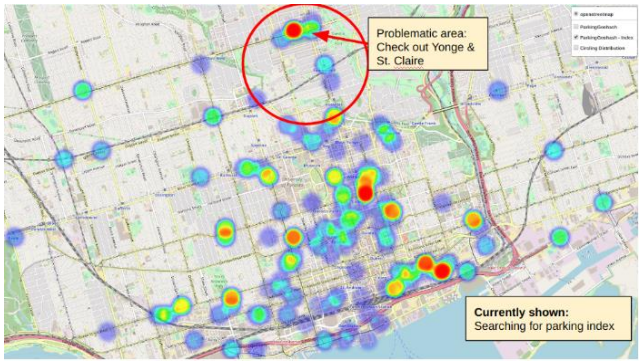

Figure 3: An illustrative heat map visualisation adapted from GeoTab White paper on searching for parking

- How's vehicle movement at different neighborhoods?
  Proposed Approach:
  - A bar plot of # of vehicles circling through different geohashes before parking at a geohash

- Is there a consistently growing number of vehicles circling around for parking at a neighborhood over a period of time?
  Proposed Approach:

    - Plot trends of circling distribution across time for the top N neighborhoods with high avg. parking time
    - Identify neighborhoods with consistently high park time ratios based on parking index measure (to be developed based on GeoTab example)

- Which are the neighborhoods in close proximity to the one with high traffic,with potential for more parking facilities?
  Proposed Approach:
    - A distance measure that identifies neighborhoods that are close to a high avg. parking time zone, based on distance, congestion levels (avg. time to park), traffic levels (avg. time to drive through), usage of current slots in the zone
    - Pick top say 5 neighborhoods based on this measure and show it on a map visualisation for each neighborhood selection

- What kind of vehicles look for parking at a neighborhood?
  Proposed Approach:
    - A bar plot of different # of vehicles: car, trucks and other multipurpose vehicles that historically park in each zone/ neighborhood
    - A plot of different types of parking facilities available at each neighborhood: on-site, off-site…

D. Modelling

I. Individual vehicles

- Linear Programming
- Adaptive multi-criteria optimization (cf. Parking Search Optimization in Urban Area
    - maximizing the convenience = combination of walking distance convenience, cost of the parking lot, estimated parking search time (in the vehicle)
    - We could make our own formula (also have to think about the case when more than one vehicle want the same parking spot), by for example giving bigger importance to the parking search time than the cost to avoid congestion, or the other way around
- Multivariate autoregressive model
    - Forecasting parking demands based on several features in the dataset.(eg. occupied number of spots, parking price, parking lot type, time, distance)

II. General Organization

- Try to develop an index that can categorize an area as high, medium, low congested based on the number of parking tickets in locality, traffic movement, number of vehicles searching for parking
- Assess, capacity level of area, if overcrowded or still available space for different type of vehicles
- Try to predict how many parking lots would be needed for a particular period of time in a particular locality. If this exceed a certain threshold (say more than available parking slots), and this happens for a consistent period of time, this area should be recommended as potential zone to place new/ more parking facilities. [the prediction will help anticipate the growing demand]

- Combine above model along with capacity indicator for a locality to see, if there's a possibility to place new parking facility, if so what types do they need more? On street or off street? Cars or medium/ high duty trucks?
- Try to compare several machine learning methods to predict parking occupancy (regression tree, neural network, support vector regression) and choose a better model to predict

E. Workload Division

We have one central dataset which is the Geotab dataset, and we have identified 6 other datasets. Each of us will work on cleaning two of these datasets, as shown in the **Data Collection** part.

We then have 6 of the primary questions that are more straightforward to answer than the others:

- How do we identify free parking spots ?
- Which are the locations the vehicles spend most time in before finding a parking spot? (this can help identify where to add more signage board)
- How's vehicle movement at different neighborhoods?
- Is there a consistently growing number of vehicles circling around for parking at a distribution over a period of time?
- Which are the neighborhoods in close proximity to the one with high traffic?
- What kind of vehicles look for parking at a neighborhood?

Therefore, each of us will tackle two questions and create appropriate visualizations for these questions.

This will help us to work together on the following questions:

- How do we decide which vehicle to place at each free parking spot, when there are several demands at the same time ?
- How to provide an optimal route for vehicles to the parking spot ?

F. Expected outcome

We would like to create an interactive dashboard displaying all our observations.

G. Related work

These are some related work on parking optimization that gave us insight for different models we could use for our problem.

Parking optimization:

- http://www.ijsimm.com/Full_Papers/Fulltext2017/text16-2_195-206.pdf
- https://drive.google.com/drive/folders/1EiP4QEy_yfmZlU7pv1XTTvMXO453icSD

Parking occupancy prediction:

- https://repositorio.iscte-iul.pt/bitstream/10071/15415/1/Predicting_Space_Occupancy_for%20Street_Paid_Parking_Master_Thesis_Marco_Silva.pdf
- http://users.jyu.fi/~miselico/papers/parking_paper.pdf