Effective Geometry of Urban Travel Patterns

Presented by **Iain McLaren**

Faculty Advisor: **Professor Saray Shai**, Computer Science

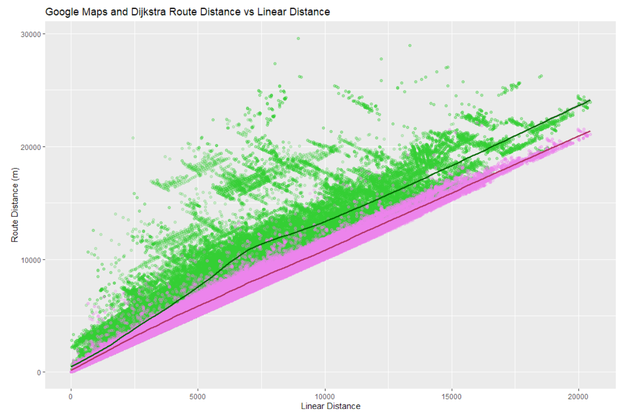
Introduction

- By abstracting systems into networks, one can use **general mathematical tools** to characterize and compare different connectivity patterns.
- Additionally, the application of **geometric tools** to the analysis, classification and comparison of networks allows new understandings to be made.
- An efficient embedding of a network in a metric space provides **natural geometrical interpretations** of topological features. In particular, many topological properties common in real-world networks emerge as natural reflections of the basic properties of an **underlying geometry**.
- In this proposal we open a new direction in the application of geometrical tools to the study of **urban networks** by building connections between road network flows and Riemannian geometry.
- By combining **geometric tools** with network analysis on urban road maps, we hope to mathematically explain features of the roads in cities that **millions use** every day.

Research Questions

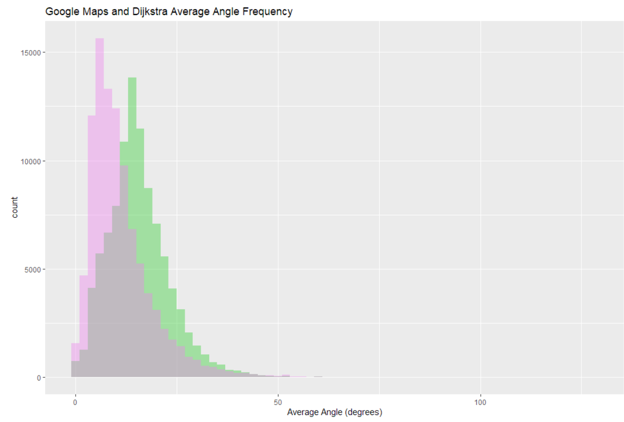
- Why are some routes through cities **windy** and others closer to straight?
- What causes a road to have a high **"basin of attraction"** (routes take a driver far out of their way to utilize this road)?
- Can we effectively model road networks in **two-dimensional** space?
- Do certain geometrical features of urban road networks lead to **congestion**?
- Are some cities' geometries more **efficient** at moving drivers throughout the system?

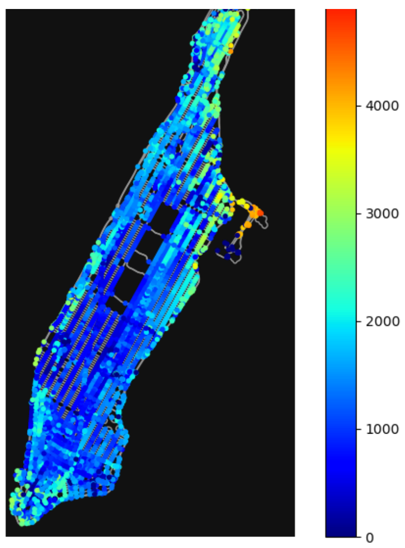
Results



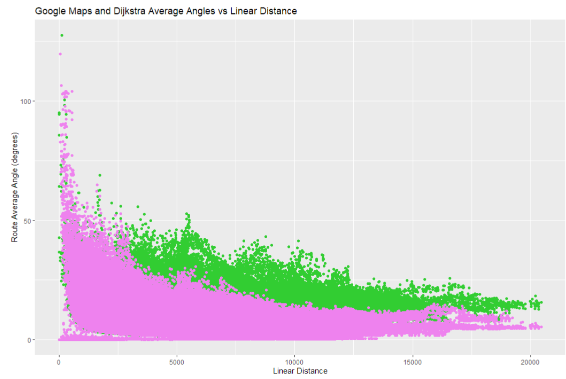
Google Maps distances (in green) and the distances of the shortest path (in violet) are very similar in short trips, but **as trips become longer, Google Maps rapidly outpaces the shortest path algorithm in distance**, showing that longer trips tend to violate standard geometry more than short trips.

We also collected data on the **angles** of all turns made in routes. We found that **Google Maps (green) was likely to have routes with more turning** as compared to the shortest path algorithm (violet).

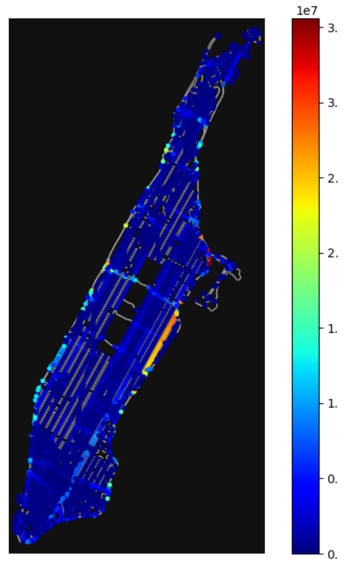




Across all of the routes we collected, we measured the **average distance** each intersection is **from the straight line path** of the route. This finds the relative 'attraction' of an intersection as a higher average distance means **Google Maps pulled the driver out of their direct path** to utilize that intersection. Some of the nodes with the **highest attraction are highways and major roads.**



When looking at the **average angles** of Google Maps routes (green) compared with those of the shortest path (violet), we once again see them follow similar trends in shorter trips but separating as distance increases. We can see that **the shortest path tends to have less turns or smaller turns than Google Maps. Interestingly, longer trips in general tend to be straighter**, likely because the route spends a considerable amount of time moving straight.



In addition to the average distance shown to the left, we also looked at the **sum of distances**. This results in data that is spread much farther apart, as some nodes like those on major highways both have **more routes utilize them** and also **tend to bring you further out of your way**. This image clearly shows just **how important those major roads are** to Google Maps in Manhattan.

Methodology

We purchased fastest routes data from Google Maps using the directions API and developed an algorithm to turn a sequence of network locations into a path of consecutive nodes in the network. In particular, the directions API takes a starting and ending location in a city and returns a sequence of (latitude, longitude) coordinates associated with each step in the directions. We obtained data on **the fastest way to get from a single source node** (i.e. street junction) in Manhattan **to every other target node in Manhattan**. We sampled around 15 sources at one single time (weekday at noon) and 1 source throughout an entire day (8am, 12pm, 4pm, 12am). With this, we analyzed the **length of Google Maps' fastest paths and compared the results with shortest paths** (computed with Dijkstra's shortest path algorithm). We also analyzed information on the **angles of turns in the Google Maps routes** using two algorithms, the first using the angle between the vector connecting the source and target nodes and the vector connecting each pair of consecutive nodes in the path, which measures the **extent to which fastest routes go "against the direction"** of the Euclidean geodesic from the starting to the ending node, and the second being a standard calculation of the angle in degrees of each turn the route makes at an interesection. Finally, we analyzed the **distance each node in a route is from the straight line** connecting the source node to the end node. All of the results above come from the data we gathered using these methods.

References

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