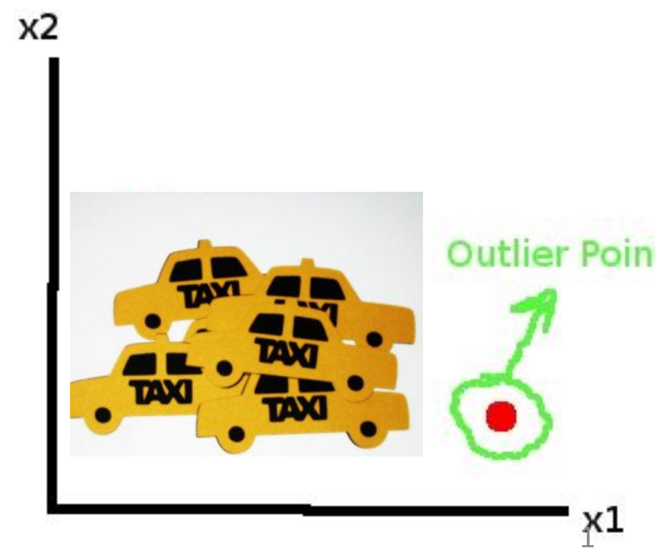
Anomaly Detection in NYC Taxi Data

Harish Pullagurla
Hari Krishna Majety
Kenneth Tran



What are Anomalies ??

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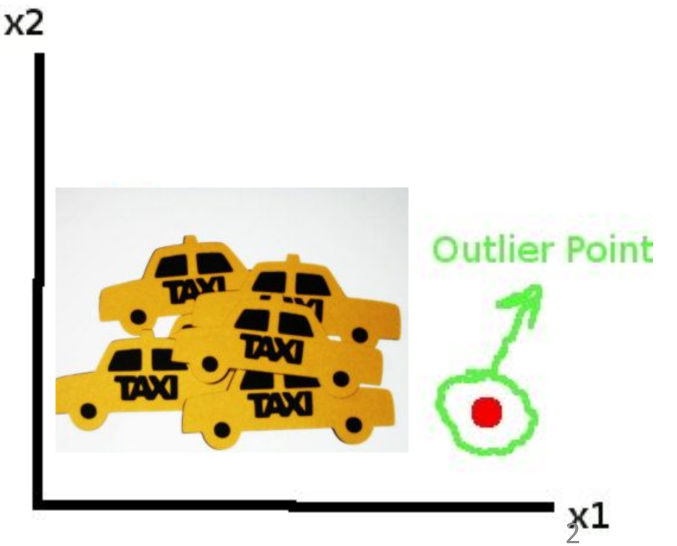

What are Anomalies ??

What is this Data Set about ??

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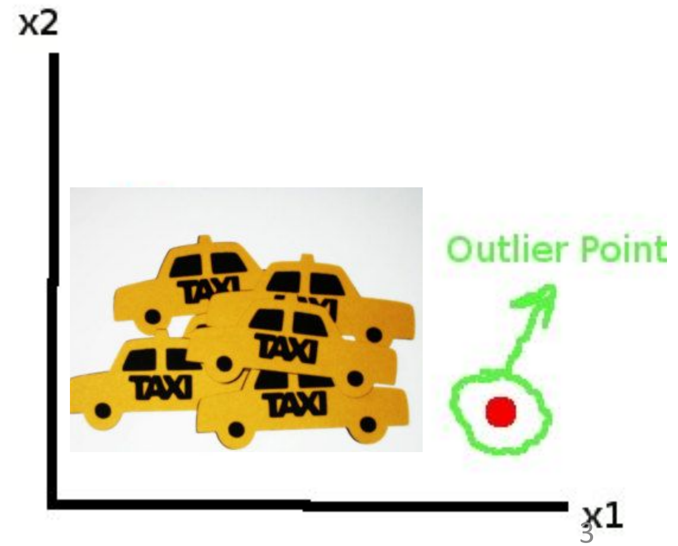


What are Anomalies ?

- The set of data points that are considerably different than the remainder of the data
- Anomaly is a pattern in the data that does not conform to the expected behaviour
- “An outlier is an observation which deviates so much from the other observations as to arouse suspicions that it was generated by a different mechanism”, (Hawkins 1980)

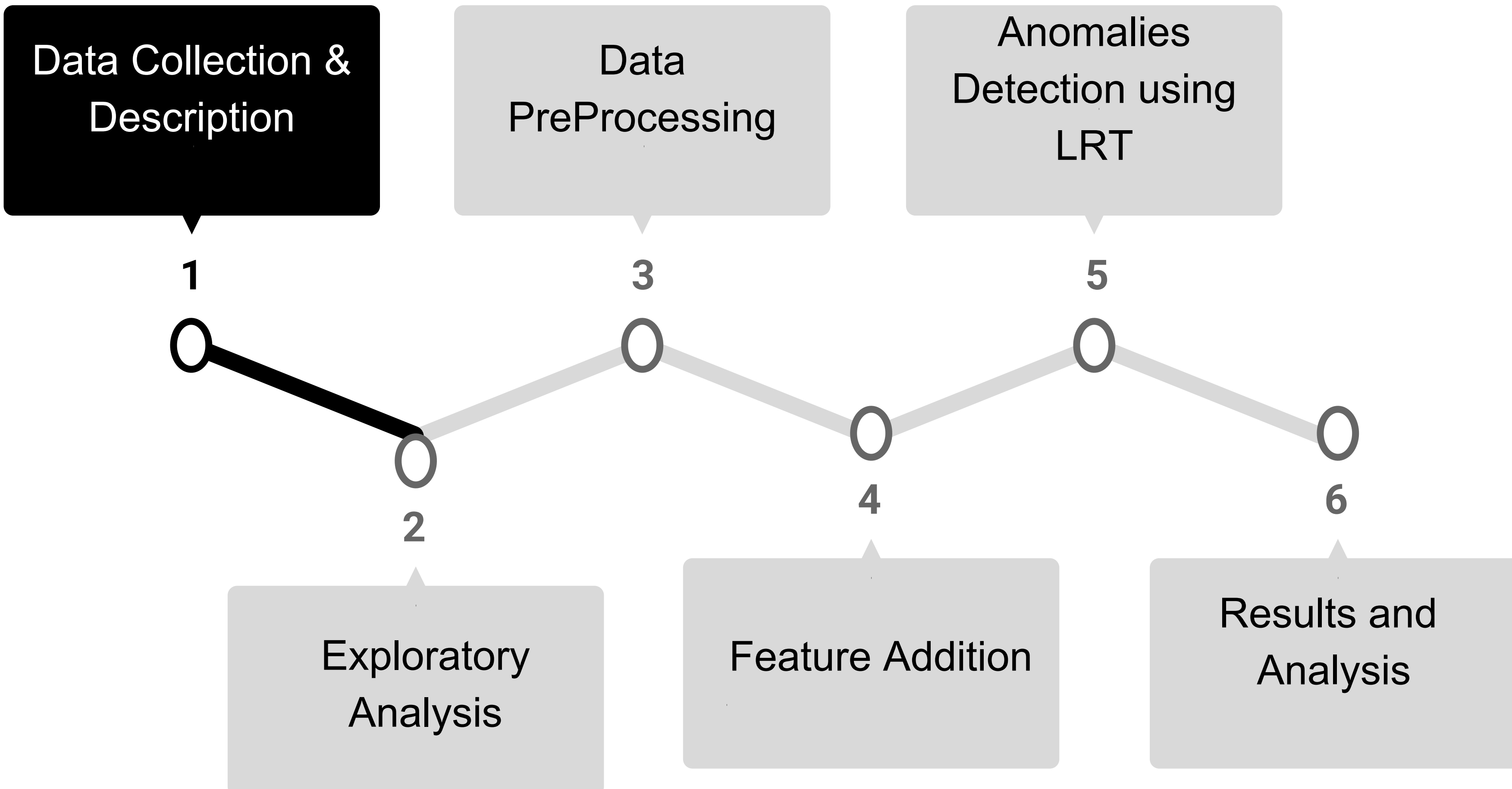
Taken From STDM Lecture Notes

Related Work

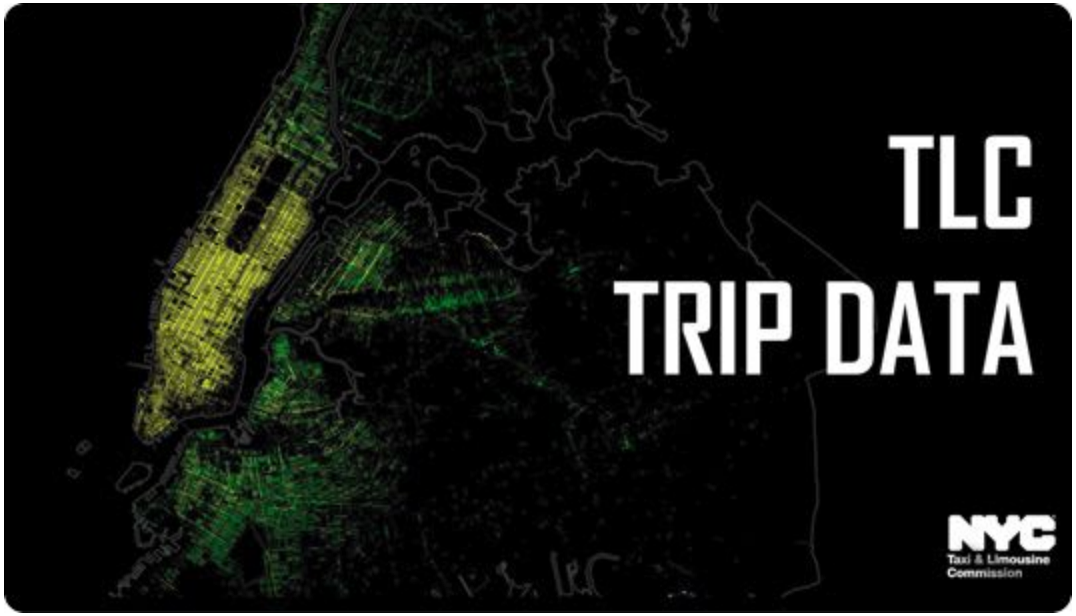
- *Wu, Mingxi, et al. A LRT Framework for Fast Spatial Anomaly Detection. Research Gate, Proceedings of the 15th ACM SIGKDD, Jan. 2009.*
  - Applying LRT to Anomaly Detection
  - Region pruning methods to reduce computation

- *Pang, Linsey Xiaolin, et al. On Detection of Emerging Anomalous Traffic Patterns Using GPS Data. Data Knowledge Engineering, North-Holland,18 May 2013.*
  - Applying Anomaly Detection LRT to specific data sets
  - Includes case study on Beijing taxi data

Pipeline


Data Collection & Description
1
Data PreProcessing
3
Anomalies Detection using LRT
5
2
Exploratory Analysis
4
Feature Addition
6
Results and Analysis

Data Set



Data Set Description

1.5 Million Trip Records
From Jan - July 2016

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Temporal Attributes - 3 dim
Pick up & drop off Time,
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Transmission Type

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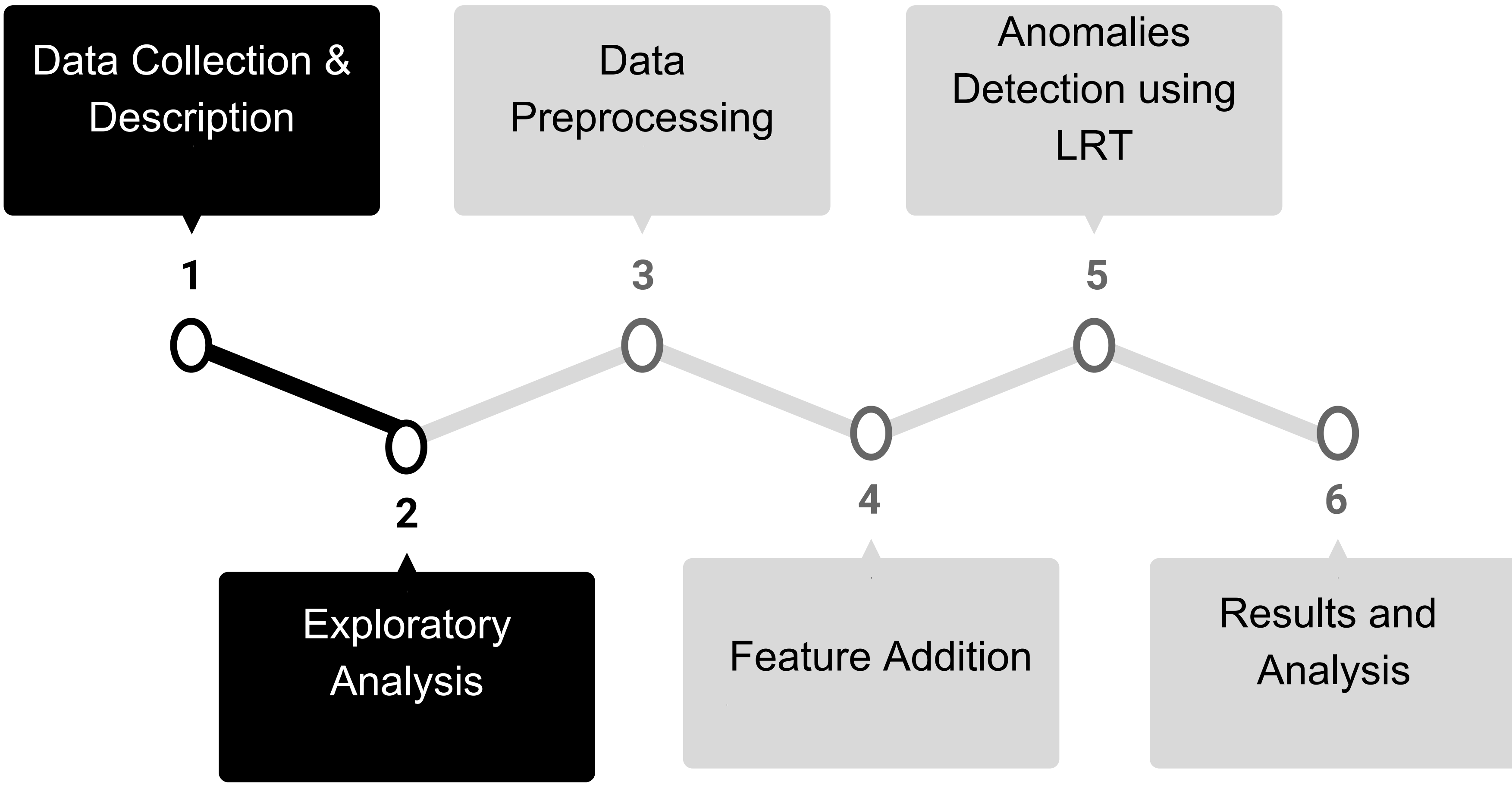
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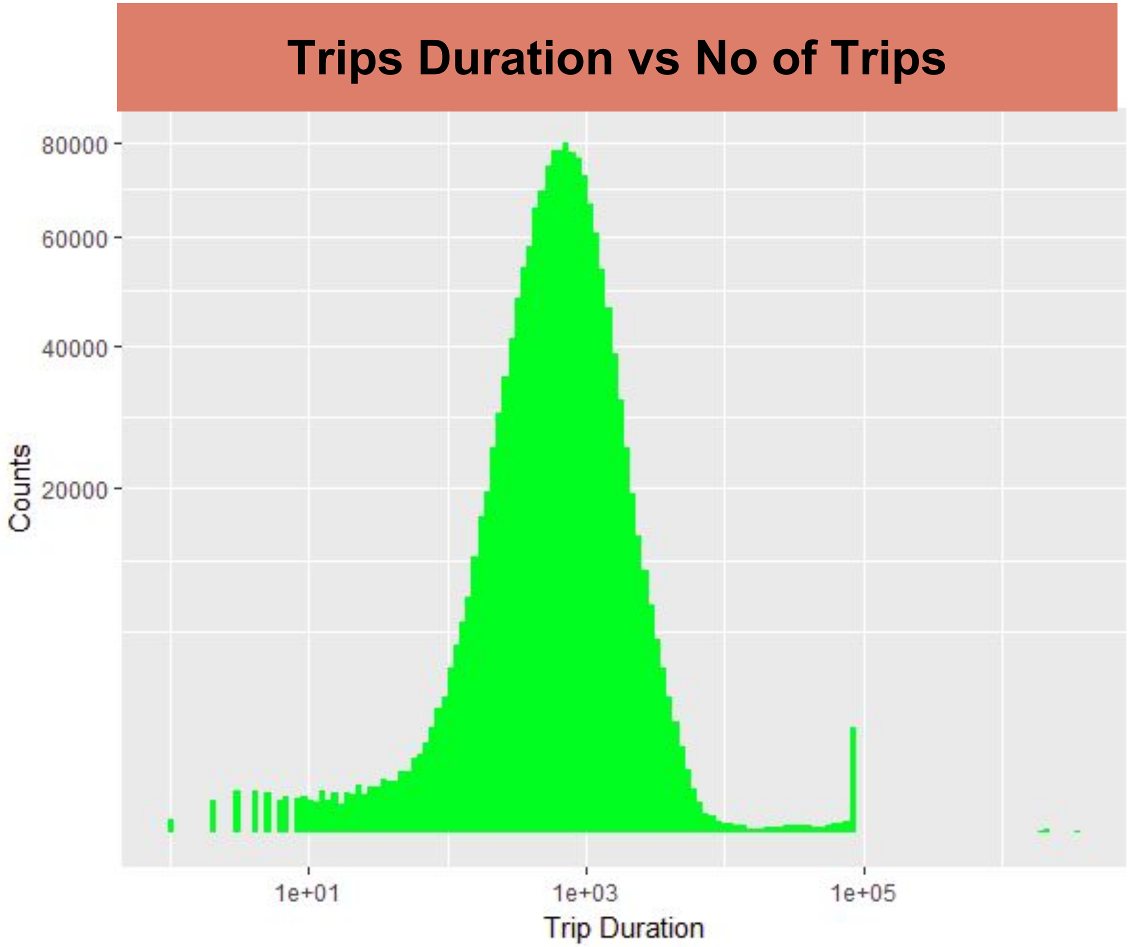
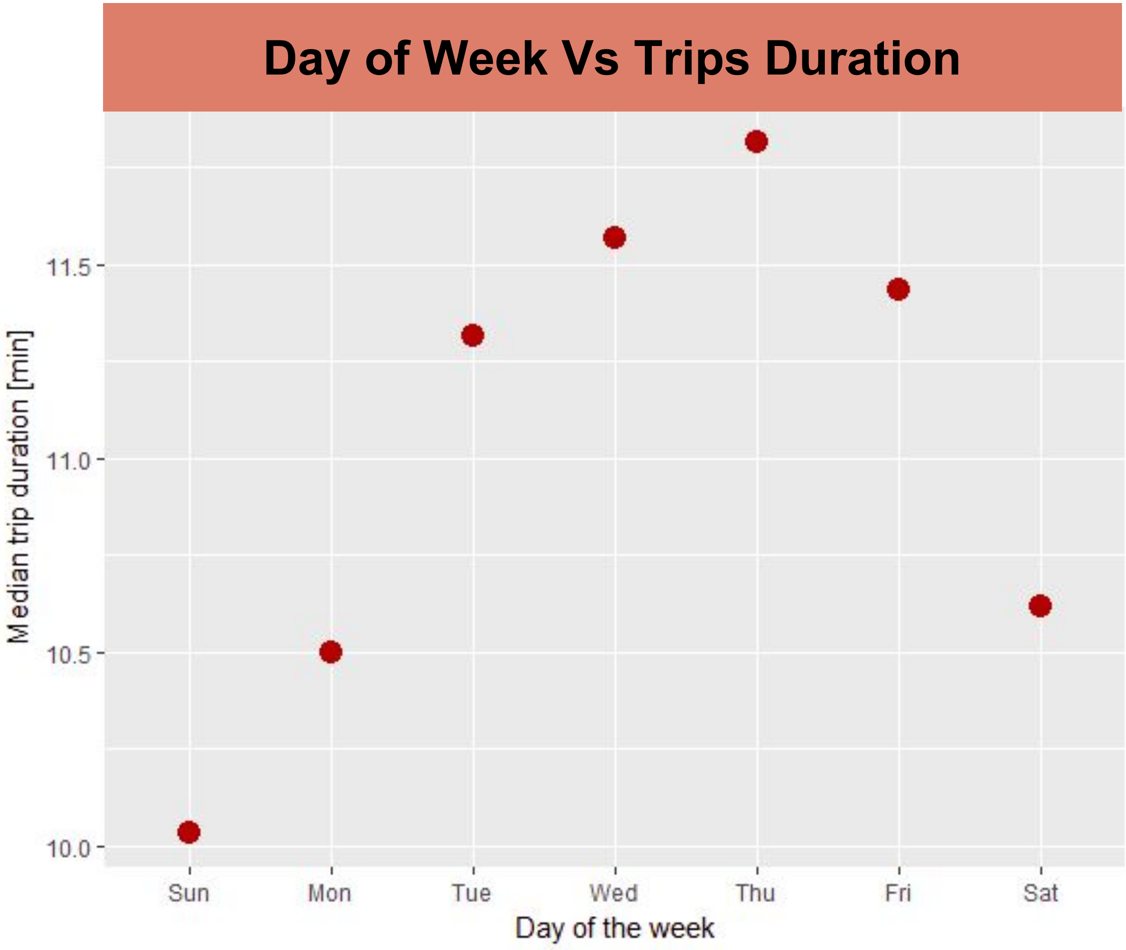
Exploratory Analysis

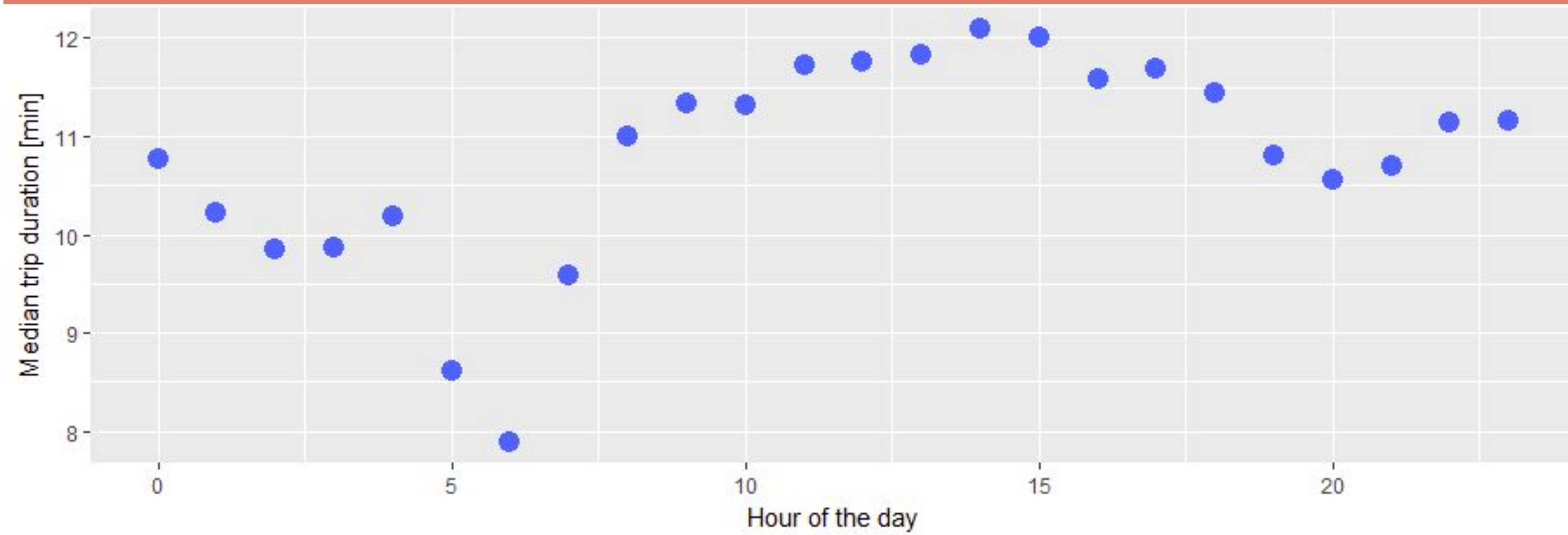


Exploratory Analysis

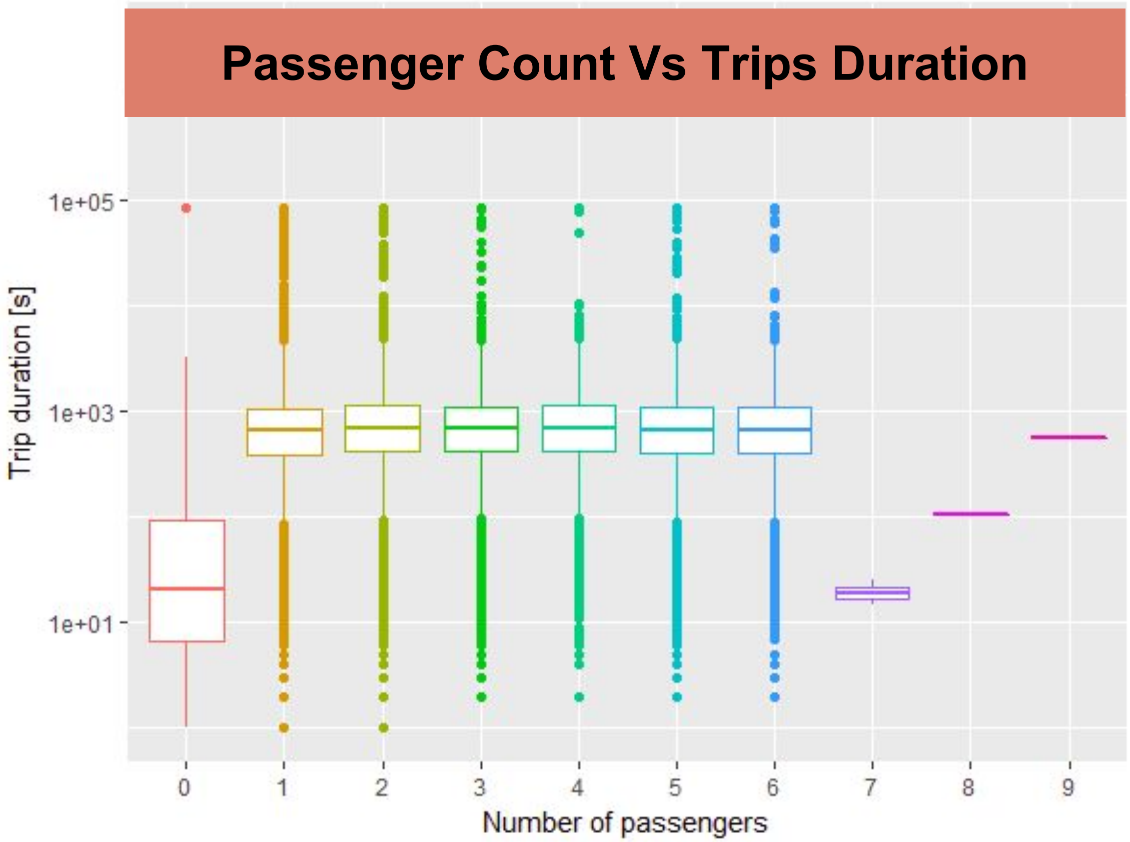


Exploratory Analysis

Hour of Day Vs Trips Duration



Exploratory Analysis



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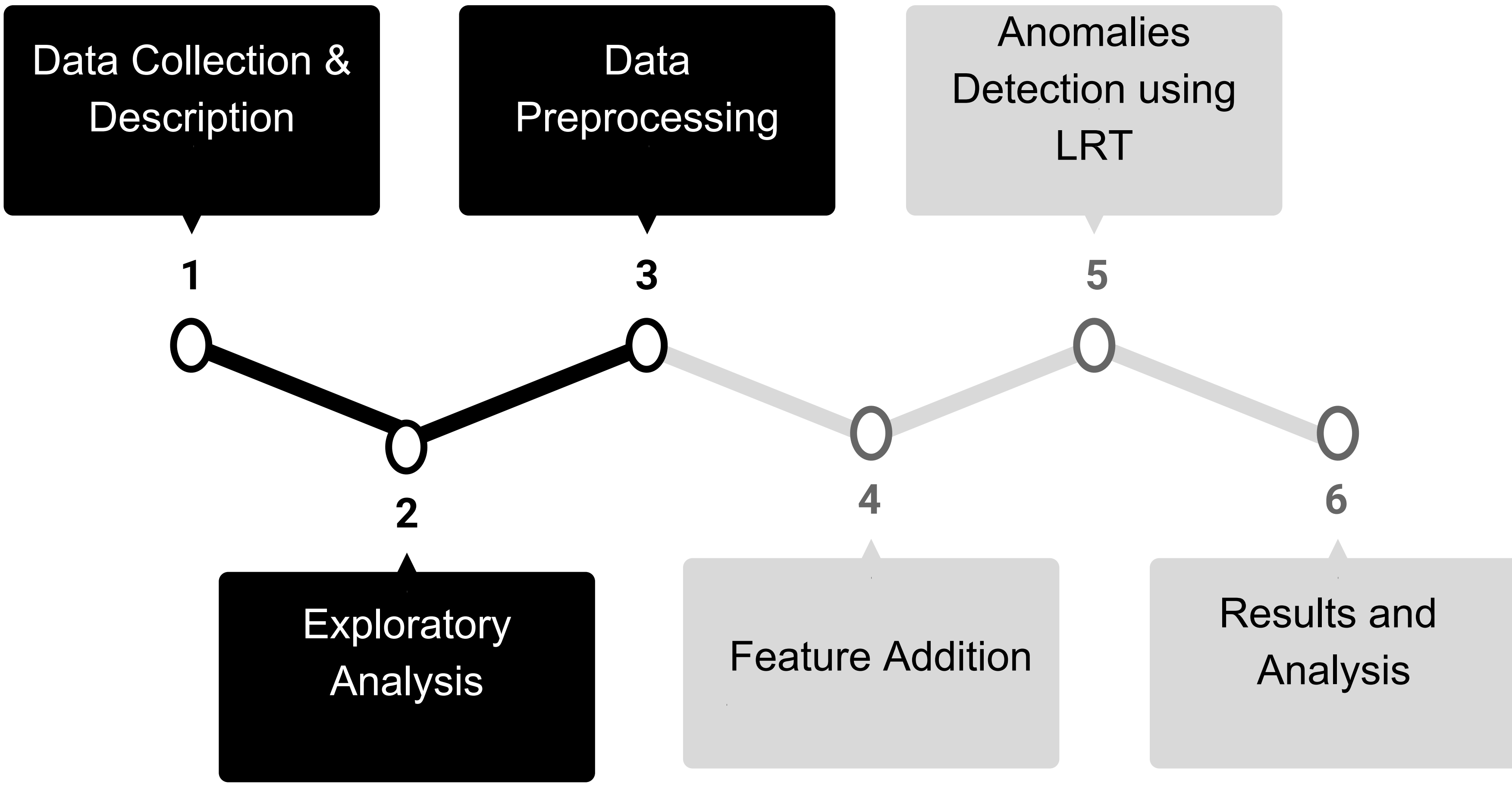
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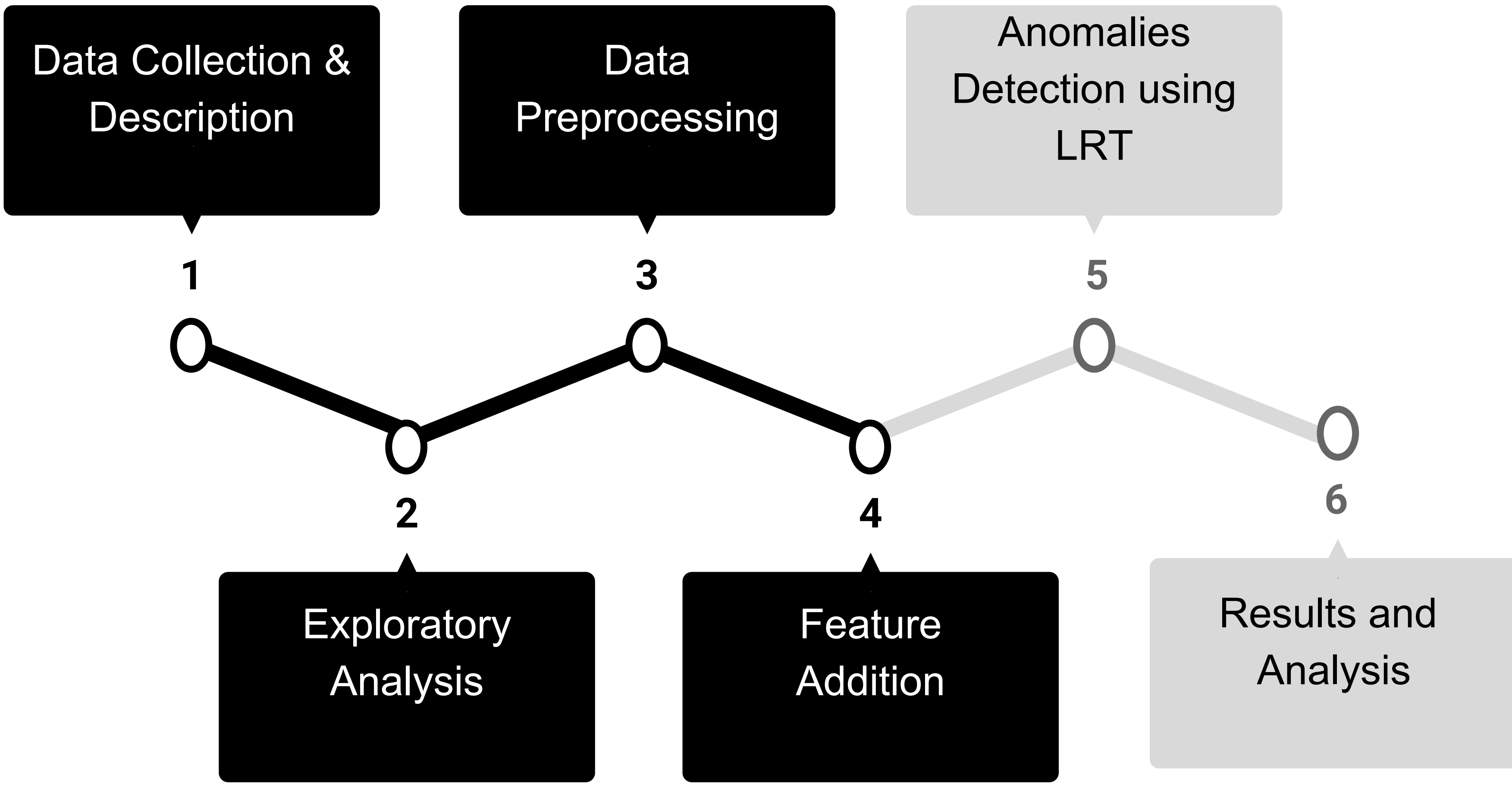
Data PreProcessing

- *Following data points were eliminated:*
  - Data points with missing attribute values
  - Duplicates
  - Pick up and drop locations which are not within the New York city limits
  - Data points with passenger counts like 0,7,8,9
  - Trip Durations which are more than 5 standard deviations away from the mean.
- *This reduced the total number of data points from 1.45 million to 1.438 million samples.*

Pipeline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Feature Addition

Existing Features

Spatial Attributes - 4 dim
Latitude , Longitude
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New Features

OSRM Data -
Gives real world travel info
like Google Maps

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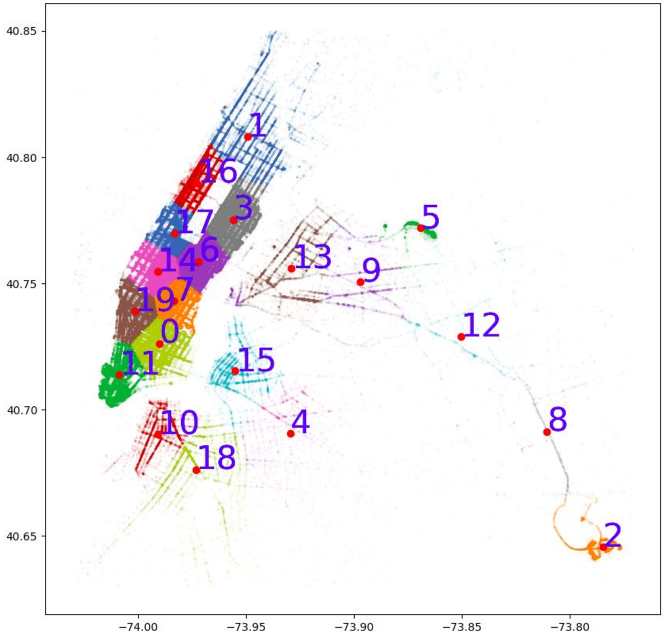
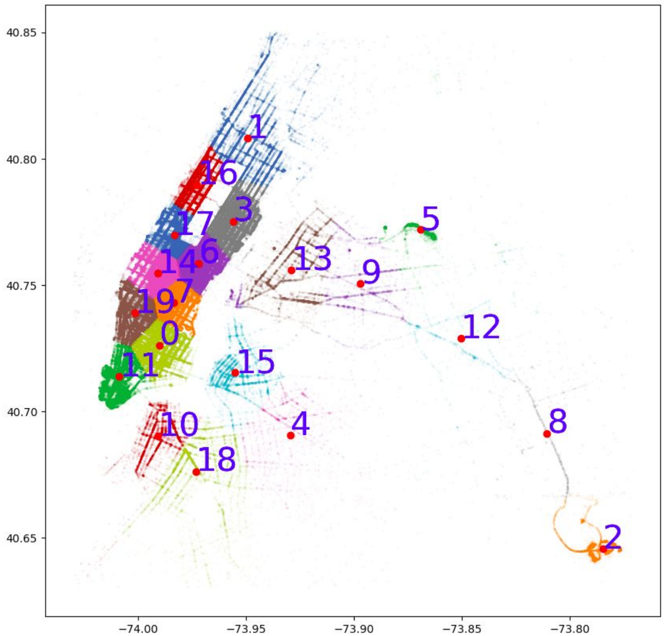
Region Clustering

Region Labeling



K means Cluster Label Map with Full Data

Region Labeling



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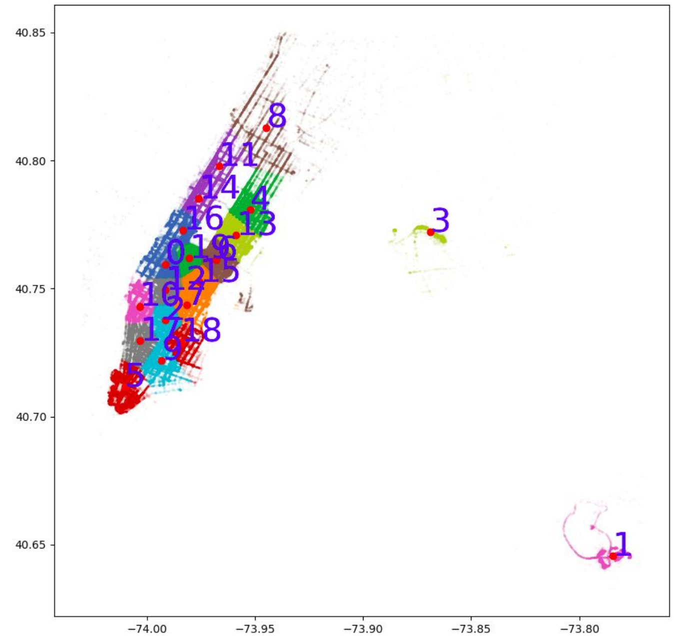
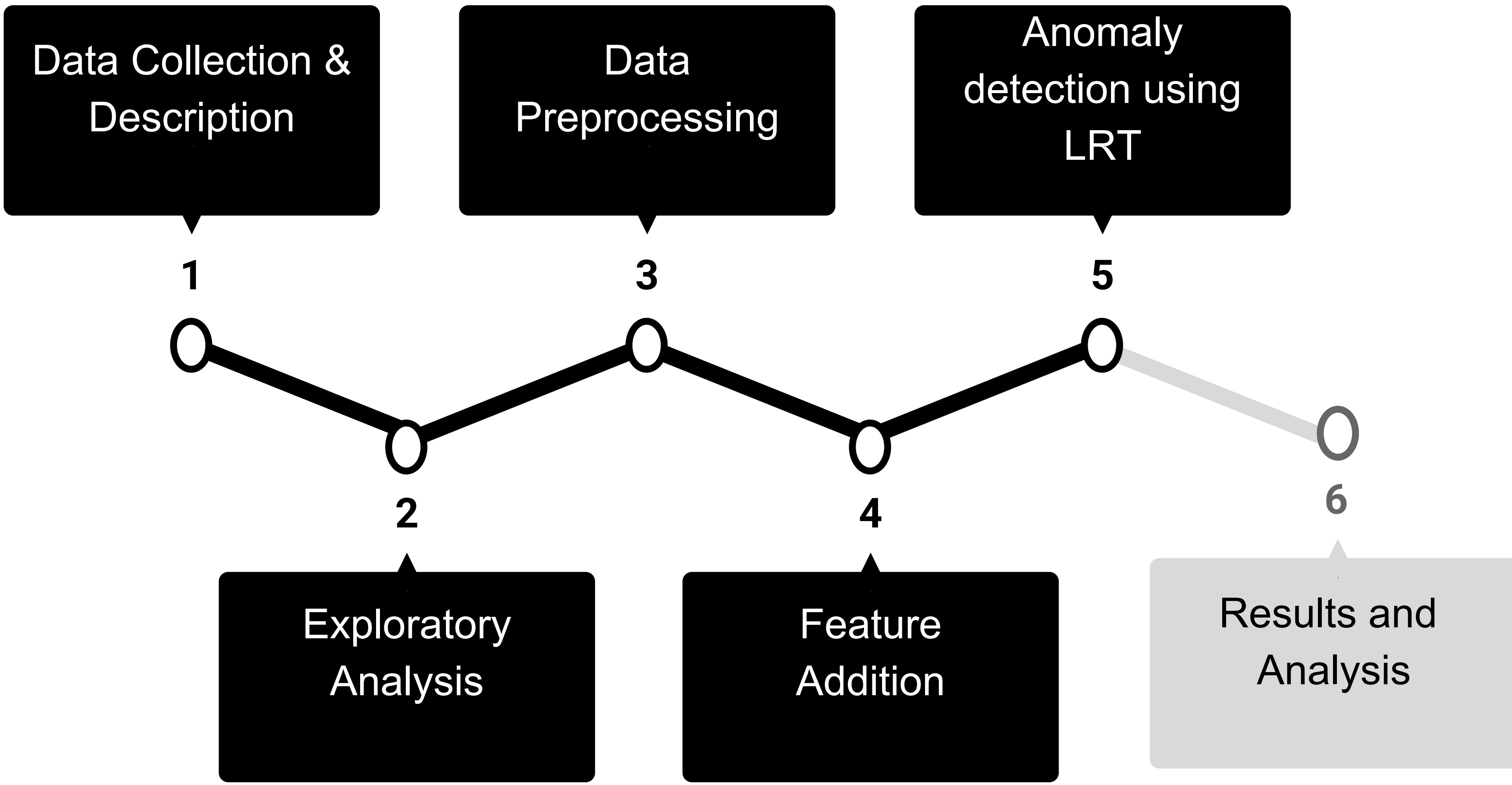


Cluster Label map after removing small clusters

Pipeline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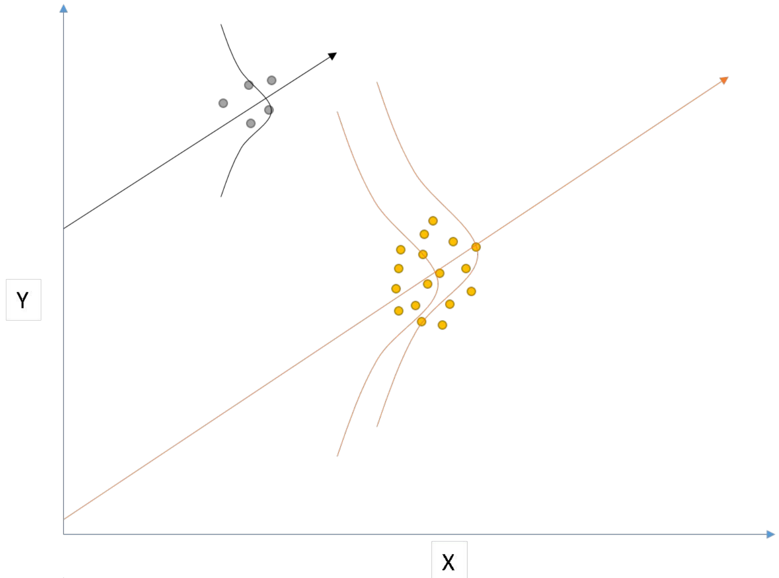
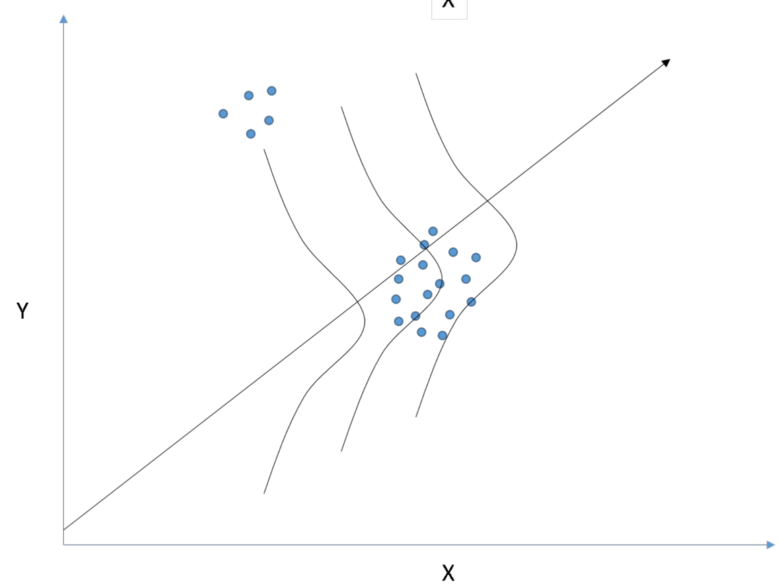
What is the Likelihood Ratio Test ?

Likelihood Ratio Test





$$\lambda = \frac{L(\theta_s|X_s)L(\theta_{\bar{s}}|X_{\bar{s}})}{L(\theta|X)}$$

Ratio of likelihoods between:

- Product of anomaly specific model and non-anomaly model
- Global model

How do we Model the Data for LRT ?

Generalized Linear Model (GLM)

The model that encompasses a group of regressions including linear regression and logistic regression.

Consists of three parts:

1. Exponential family that predicted value follows
2. Linear predictors (i.e. $b_1x_1 + b_2x_2$)
3. Link function that maps linear predictors to predicted variables

Examples:

Linear Regression: Predicted follows normal with an identity link

Logistic Regression: Predicted follows Bernoulli with a logit (or inverse sigmoid) link

Data Subsampling

Assumption : Data is homogeneous, it models similarly for all subsets

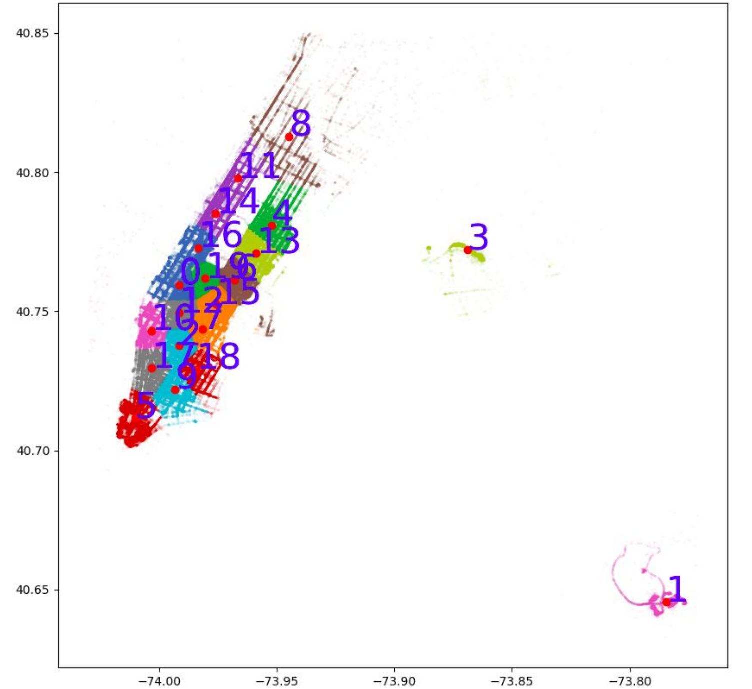
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday

Day Sample

Hour Sample - 8 am - 12 am

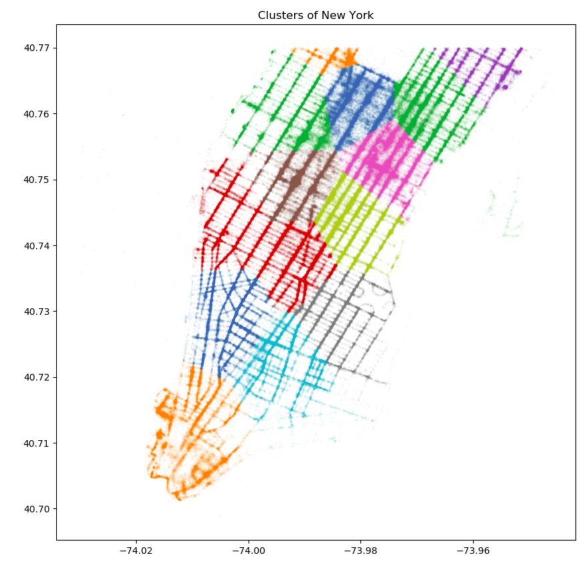
Model 1 - Spatial Anomalies

- Subset data by spatial information
  - Use the K-Means clusters performed in pre-processing
- Model all data using generalized linear model (GLM)
- For each different region, model data within the region and outside of the region, using same GLM configurations
- Compute the likelihood ratio for each region



Model 2 - Temporal Anomalies

- Subset data by Temporal information
  - Consider only Lower Manhattan Region
  - Use variable day of year
- Model all data using generalized linear model (GLM)
- For each different time segment, model data within the time segment and outside of the time segment, using same GLM configurations
- Compute the likelihood ratio for each time segment



Pipeline

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Demo

Results and Conclusion

- *Spatial Analysis*
  - Top two anomalous regions were the JFK and La Guardia Airports in the city

Results and Conclusion

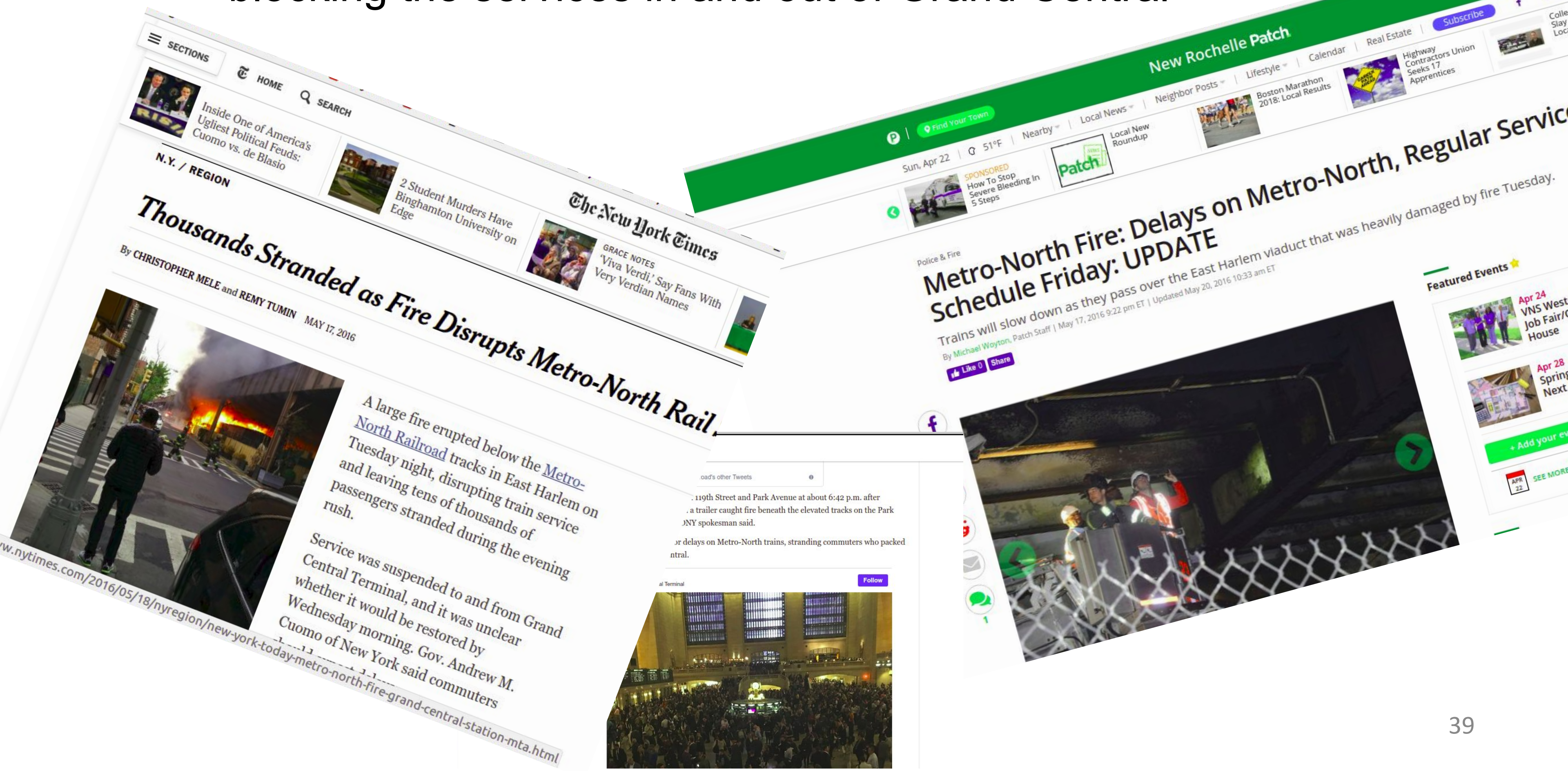
- *Temporal Analysis*
    - Most anomalous - January 26th - After New york was hit by biggest blizzard since 1869.

Results and Conclusion

- *Temporal Analysis*
  - Followed by June 8th - President Obama tapes a show with Jimmy Fallon in Time Square

Results and Conclusion

- *Temporal Analysis*
    - Followed by May 16 - Fire under Metro North track in Manhattan blocking the services in and out of Grand Central



Future Work

- Spatio-temporal analysis(Computationally intensive)
- Considering seasonality during temporal analysis
- Addressing positive correlation between data points and their likelihood values.

Project Learnings

- Different Modeling Strategies - MLE , GLM
- Likelihood Ratio Test and ways to incorporate it with NY Taxi cab data