Analysis of delays on the New Jersey railway network

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Outline

1 Introduction

NJ Transit + Amtrak (NEC) Rail Performance dataset available on Kaggle

- 2nd largest railway network in the US in terms of number of passengers
- Commuting between NJ and NY

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Evaluating delays and identifying their causes is essential

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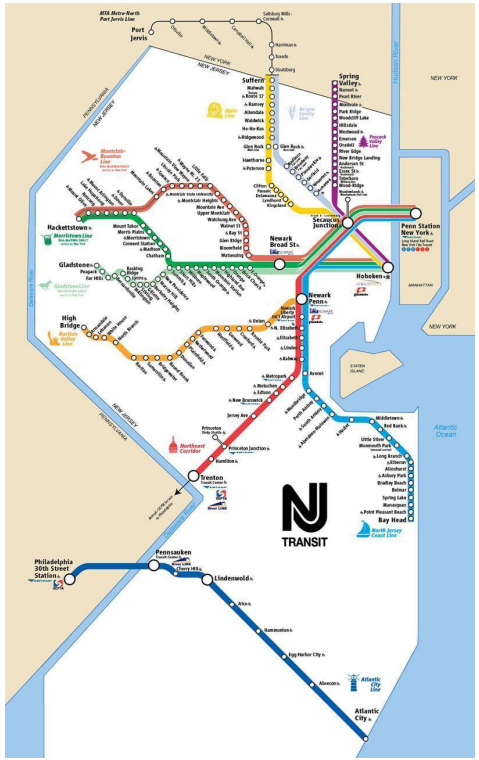
How are delays distributed in the network?

Can we predict them?



2 Preprocessing

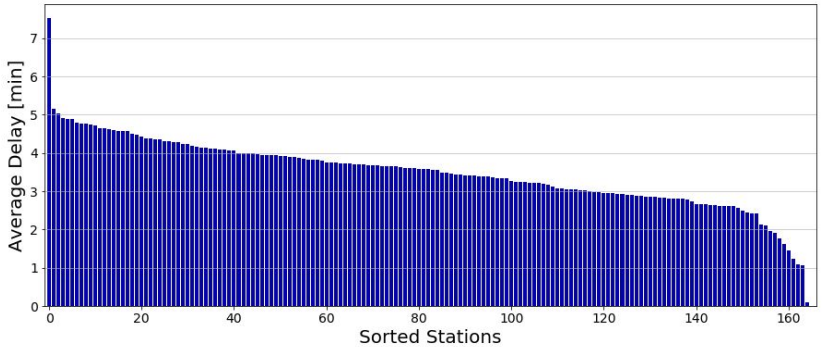
Dataset structure:

- Train trips for the NJ transit network are available at stop-level and with minute resolution
- Train trips from March 1, 2018 to April 30, 2019
- Only for March 2018:

Observations	Stations	Lines	Trains
243028	165	11	1319

How to evaluate delays?

- Average delay per station during the month of March 2018

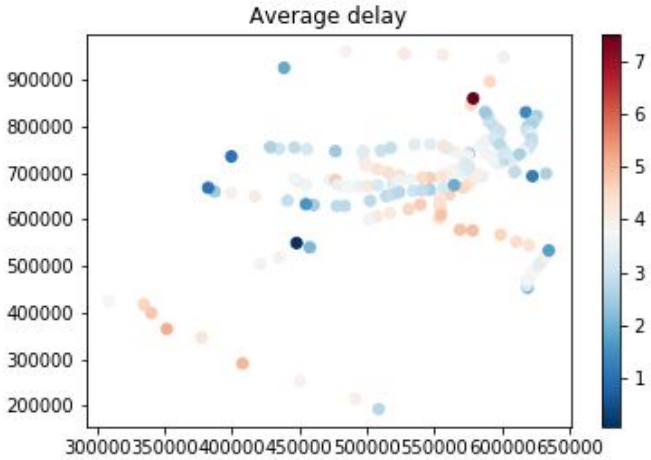


2 Preprocessing

Choice of metrics:

Objective: Find a scheme for data aggregation along each station

- Accentuation of node delays between stations
- Four different potential metrics have been attempted
- Cumulative sum and mean have shown to perform the best



Data filtering:

Objective: Noise elimination

→ Exclusively considering the weekdays and removing weekend delays

→ Removing remote stations with no direct interaction with the rest of the network

→ Filtering by inbound and outbound trains to take into account directional variation of delays

3 Clustering

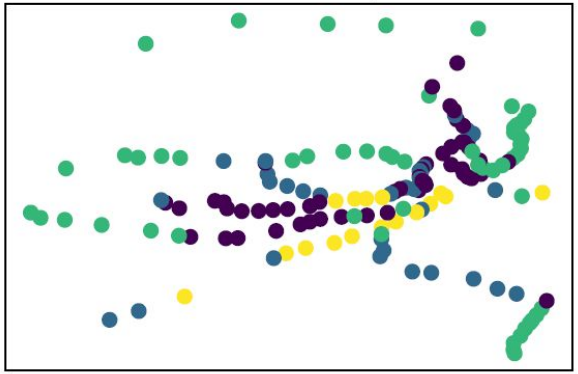
Spectral clustering:

- Similarity of cumulative delays or number of trains crossing each station.

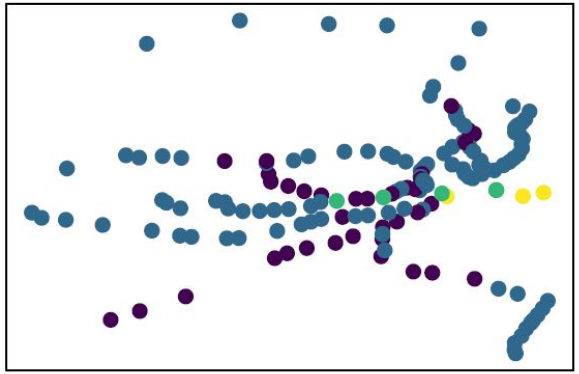
$$\omega_{ij} = \exp\{-|x_i - x_j|/2\sigma^2\}$$

- Difficult to tune σ and ε to get only one connected component: adjacency is not sparse.
- Misleading results from 4+ clusters.

Based on delays



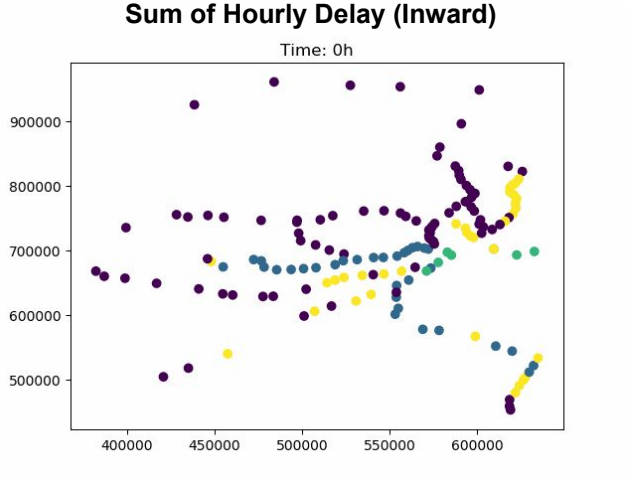
Based on no. of trains

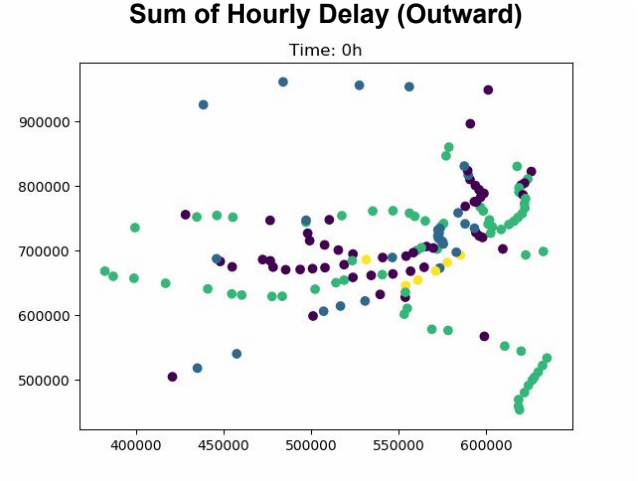


3 Clustering

k-means:

- Used to track down how clusters will vary over the day for inbound and outbound trains
- Helps the operator to identify problematic stations
- Gets insight on how delay propagates in the network
- More than 4 clusters lead to chaotic results



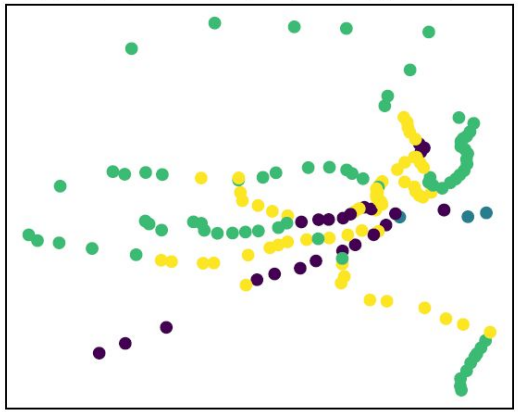


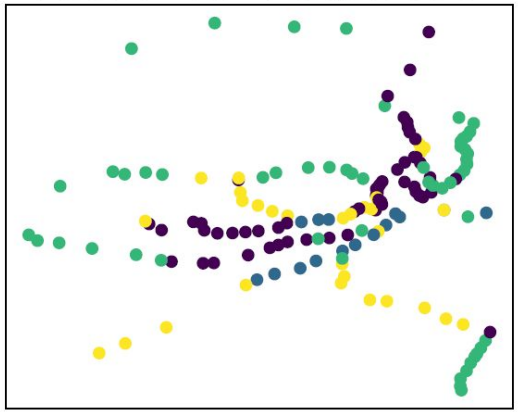
3 Clustering

k-means:

Initial Assumptions: Train frequencies are connected to cumulative delay levels in the network and distinction should be made between central and peripheral stations

- Possible to detect terminal stations for each graph
- Assumption validated with respect to spatial clustering of stations
- Similarities observed between clusters of the two graphs

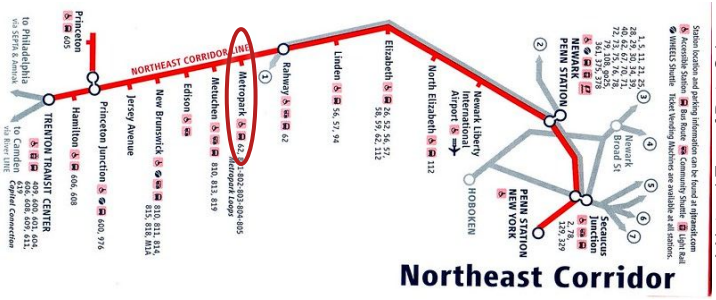




4 Prediction of delays

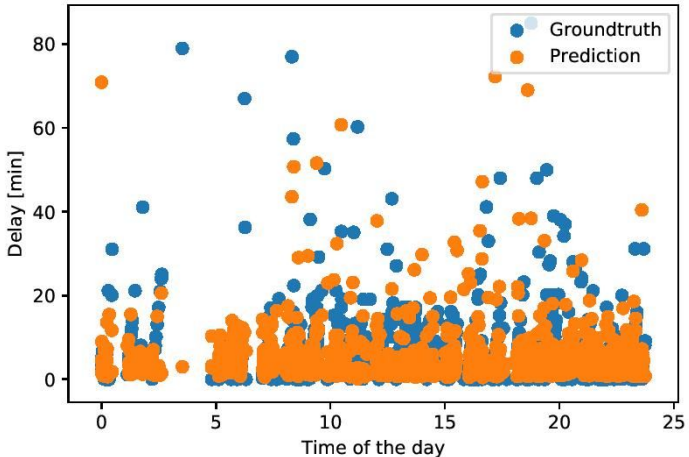
RNN with LSTM:

- **Preprocessing :** [#observations, #previous stations, #features]
  - 19403 observations
  - Features : time of arrival and delay for a given stop + the four previous stops



- **Model :**
  - Trained on one-month data for a single line *Northeast Corridor*, the features at all stops have been considered except for the stop chosen for the test set : *Metropark*
  - Prediction for the delays at *Metropark*

- **Results :**
  - Prediction of delay across the time of arrival at *Metropark* station during 24h
  - 20% accuracy
  - 10 min MSE



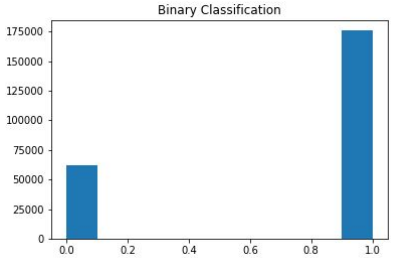
4 Prediction of delays

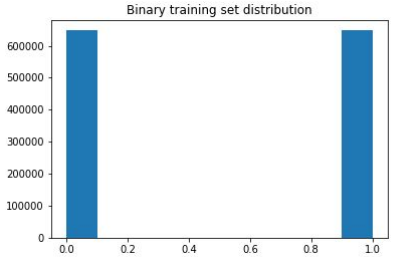
ANN Binary Classification:

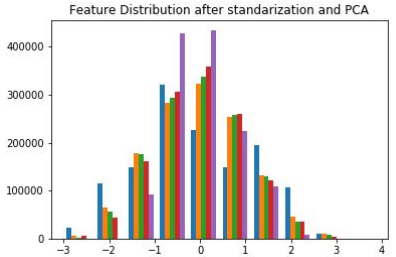
- **Preprocessing :**
  - 1038522 observations
  - Features : train_id, stop_sequence, line, day and time
  - Output: 0 if delay less than 1 min, 1 otherwise
  - Data standardization and PCA (d = 5)

- **Model :**
  - ANN:
    - 9 hidden layers of 30 nodes each
    - 2 dropout layers with rate 0.2
  - Training over one year, test on 1 month

- **Results :**
  - 62 % of accuracy on a balanced set
  - Difficult to improve prediction



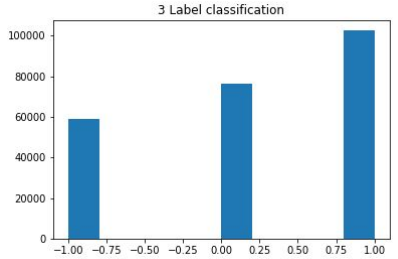


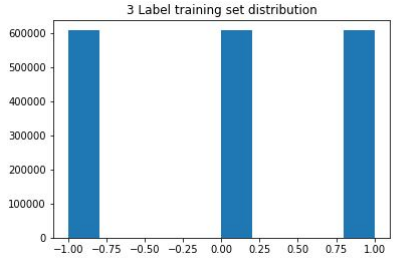


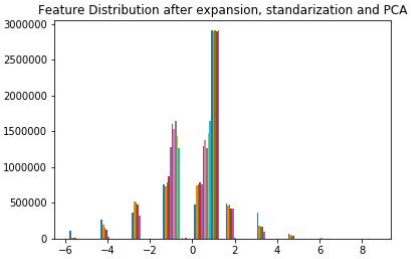
4 Prediction of delays

ANN Multi-label Classification:

- **Preprocessing :**
  - 1458562 observations
  - Features : train_id, stop_sequence, line, day and time
  - Output: -1 if delay less than 1 min, 0 if delay between 1 and 7 min and 1 otherwise
  - MinMax scaling and feature expansion with exp(X), sin(X) and cos(X)
  - Data standardization and PCA (d = 15)
- **Model :**
  - ANN:
    - 9 hidden layers of 30 nodes each
    - 2 dropout layers with rate 0.2
  - Training over one year, test on 1 month
- **Results :**
  - 41 % of accuracy on a balanced set
  - Difficult to improve prediction







5 Conclusion

Clustering:

- Correlation between node position, delay, and train frequency at each station is obvious for the central and peripheral stations
- Results are inconclusive for intermediate stations

RNN:

- Could possibly be a powerful tool
- Requires a lot of parameter tuning and training

ANN:

- Not the best tool to model the delay prediction problem
- A Graph based machine learning model maybe more adapted for our application

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