ASONAM 2018 Presentation

# Multi-task Learning for Transit Service Disruption Detection

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Virginia Tech Invent the Future

Discovery Analytics Center

# Transit Service Disruption

- Patroller inspection
  - Limited service areas are covered
  - Lack of incident detection sensitivity
  - Incidents reported after inspection
- Twitter
  - Higher coverage rate of service areas and incident reasons (e.g., fire, door, and track problem)
  - More quickly response to metro service disruption incident
  - People tweets about metro service only when they want to complain

# Transit Service Disruption

**TerribleWMATA**
@TerribleWmata
Follow

@unsuckdcmetro Georgia Ave station closed due to fire, major delays

**Nikesh Amin**
@nikeshamin
Follow

@unsuckdcmetro @FixWMATA @Metrorailinfo Been waiting over 50 minutes, in McPherson Sq, for a train, orange or silver, heading my way. Even WMATA's ridiculous delays get ridiculously delayed.


**Christopher J. Nellum**
@chrisnellum
Follow

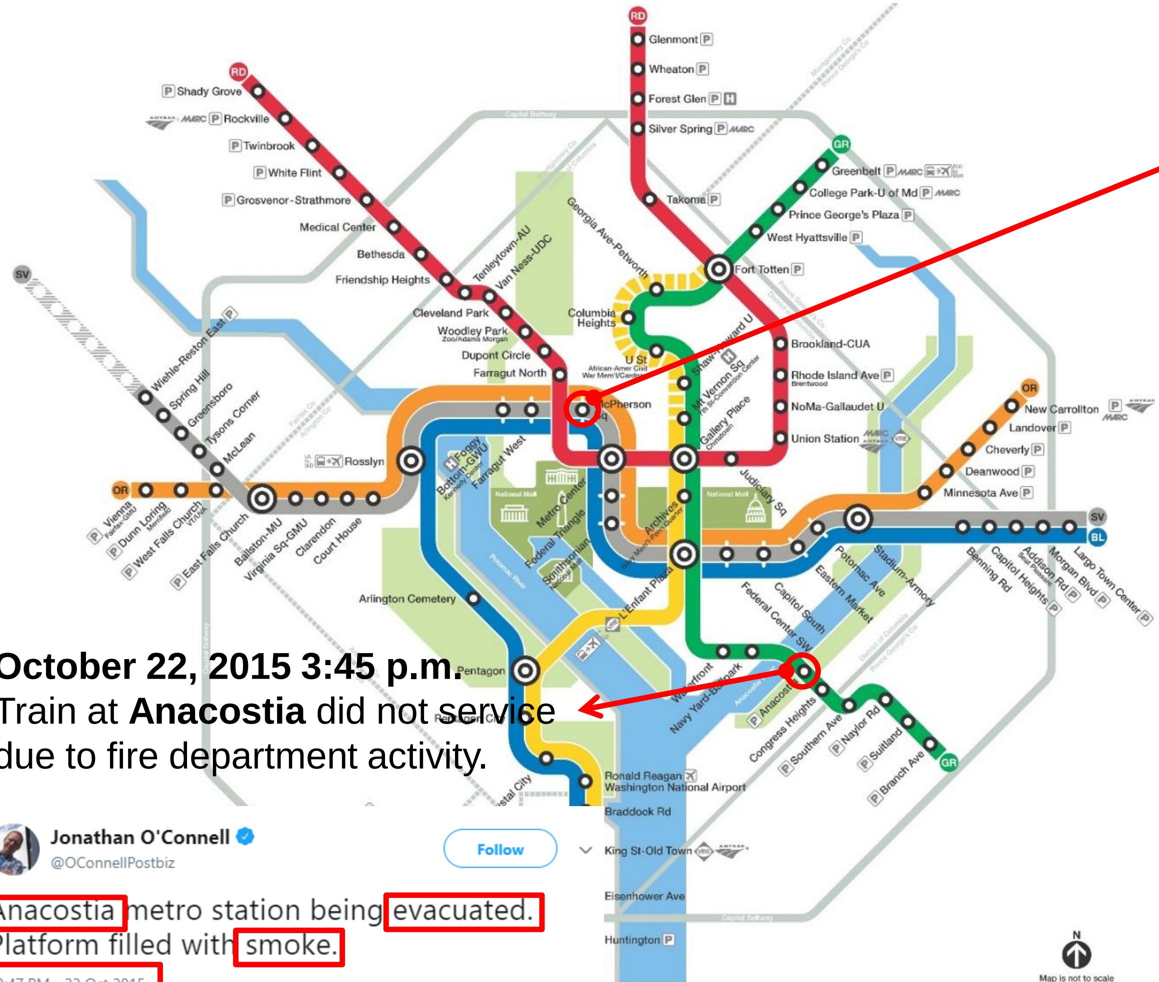
@nbcwashington @shomaristone Just watched a freight train derail outside of my window near the Rhode Island @wmata station. Crazy!

**Faiz Siddiqui**
@faizsays
Follow

Major power problems on #wmata this morning, amid partial BL shutdown and round-the-clock OR/SV single-tracking

Metro is accessible.

# Transit Service Disruption




**October 21, 2015 1:34 p.m.**
Train at **McPherson Square** was delayed 26 minutes due to a brake problem.
**(Orange, Silver and Blue)**

**Helen Mason** @HelenDc
Follow

25 minutes for a train @McPherson Square,,,, in London you could have 25 trains in that time... @unsuckdcmetro oh I miss @TfL

1:00 PM - 21 Oct 2015

**Metrorail Info** @Metrorailinfo · 21 Oct 2015
Replying to @mmstevens2012
@mmstevens2012 Hi! Sorry for the inconvenience. Where are you waiting & what direction are you traveling? Thank you.
1 1

**Michelle Stevens** @mmstevens2012
Follow

Replying to @Metrorailinfo
@Metrorailinfo Heading to Wiehle from McPherson Square. Took orange from Mc to East FC. Train here soon but long waits seem commonplace.

2:02 PM - 21 Oct 2015

**October 22, 2015 3:45 p.m.**
Train at **Anacostia** did not service due to fire department activity.

**Jonathan O'Connell** @OConnellPostbiz
Follow

Anacostia metro station being evacuated. Platform filled with smoke.

12:47 PM - 22 Oct 2015

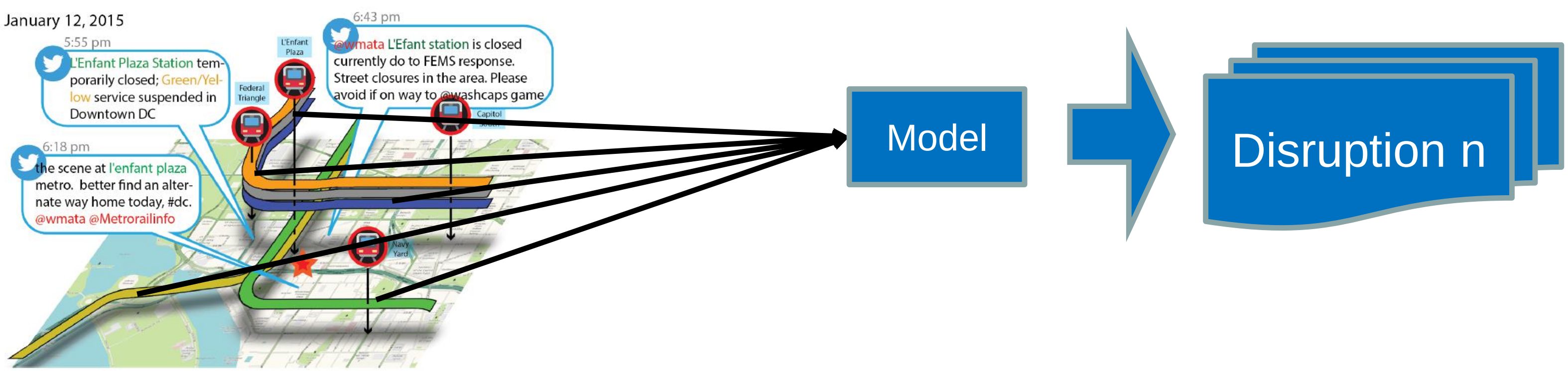
# Problem Formulation

- Input
  - $X_t^c$ is the feature vector for metro line $c$ during time window $t$.
  - Learn a function: $F_c(X_t^c) \rightarrow Y_t^c$,
- Output
  - $Y_t^c \in \{0,1\}^{1\times T}$ determine if a disruption event happens at time window $t$
- Features
  - Selected sentiment keywords from StaticTwitterSent dictionary

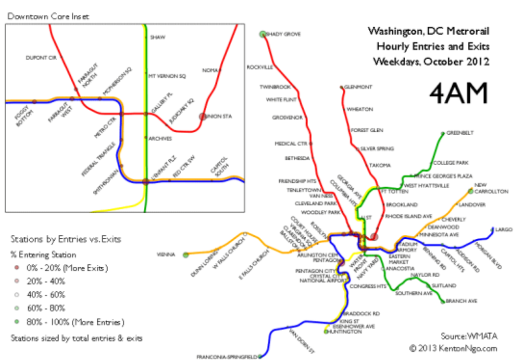
# Transit Service Disruption Detection

## One model for all metro lines

**Pro: sufficient data to train**




**Con: ignore the metro line's exclusive characteristics (ridership, etc.)**




source: gifer.com

100 complaints have different meaning to these two stations

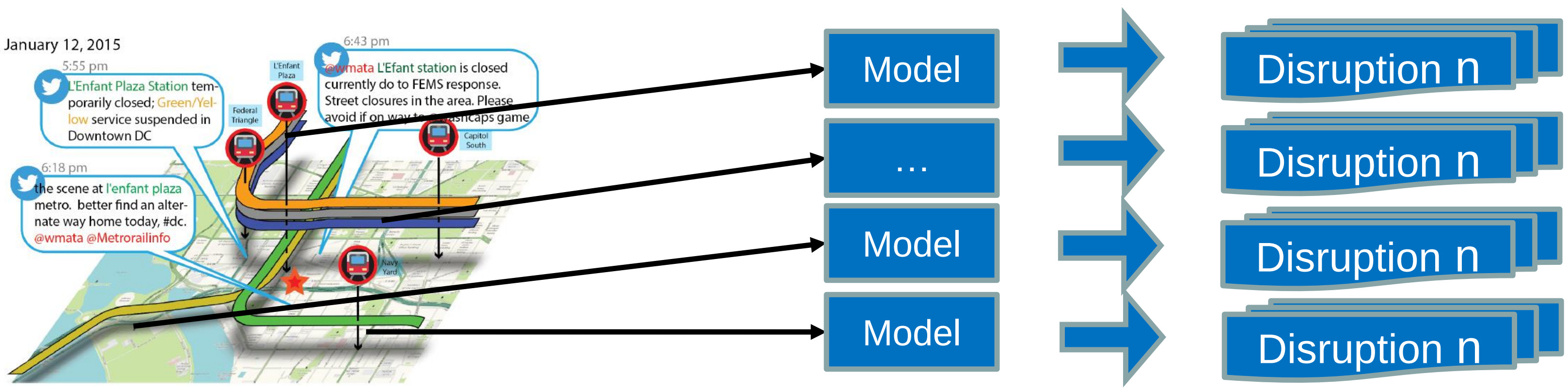
Station: Deanwood
Average weekday passenger boardings: **637**

Station: Farragut North
Average weekday passenger boardings: **21989**

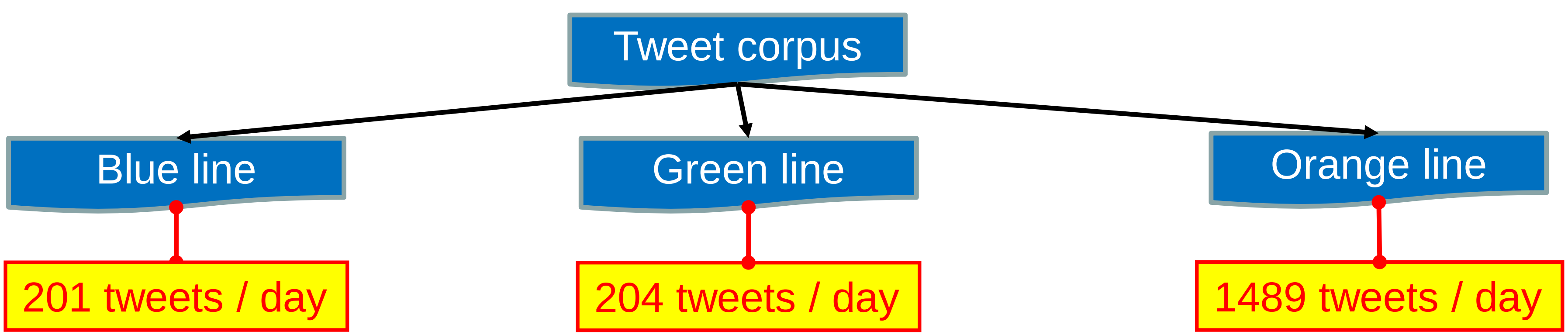
# Transit Service Disruption Detection

## One model for each metro line

**Pro: consider the metro line's exclusive characteristics**



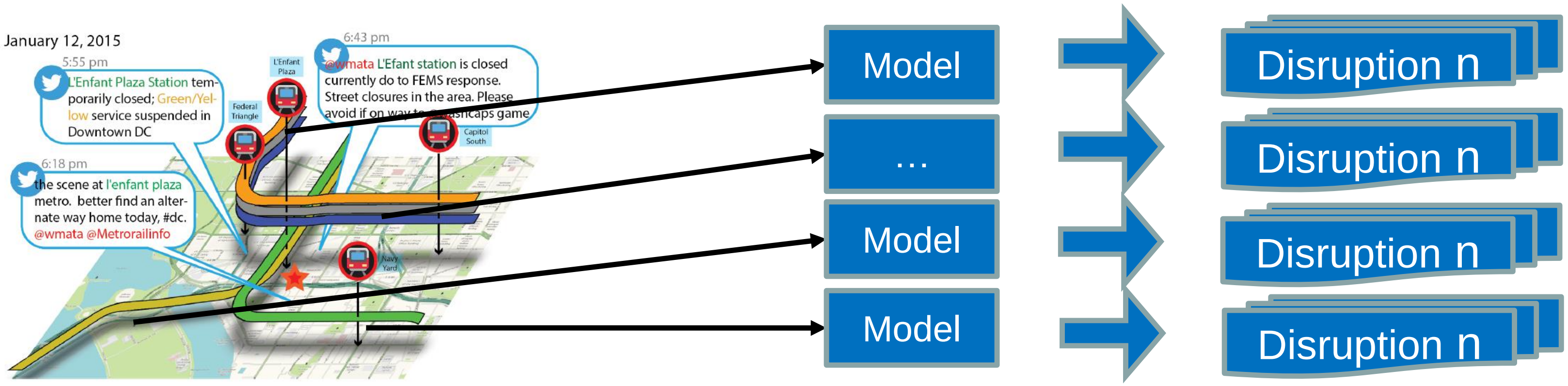

**Con: performance is limited when the training data is not sufficient**



# Transit Service Disruption Detection

## One model for each metro line

**Pro: consider the metro line’s exclusive characteristics**




**Con: relatedness between metro lines are ignored**

Orange and silver lines share 83% of their stations

Different metro lines share similar “complaint vocabulary”

# Challenges we address

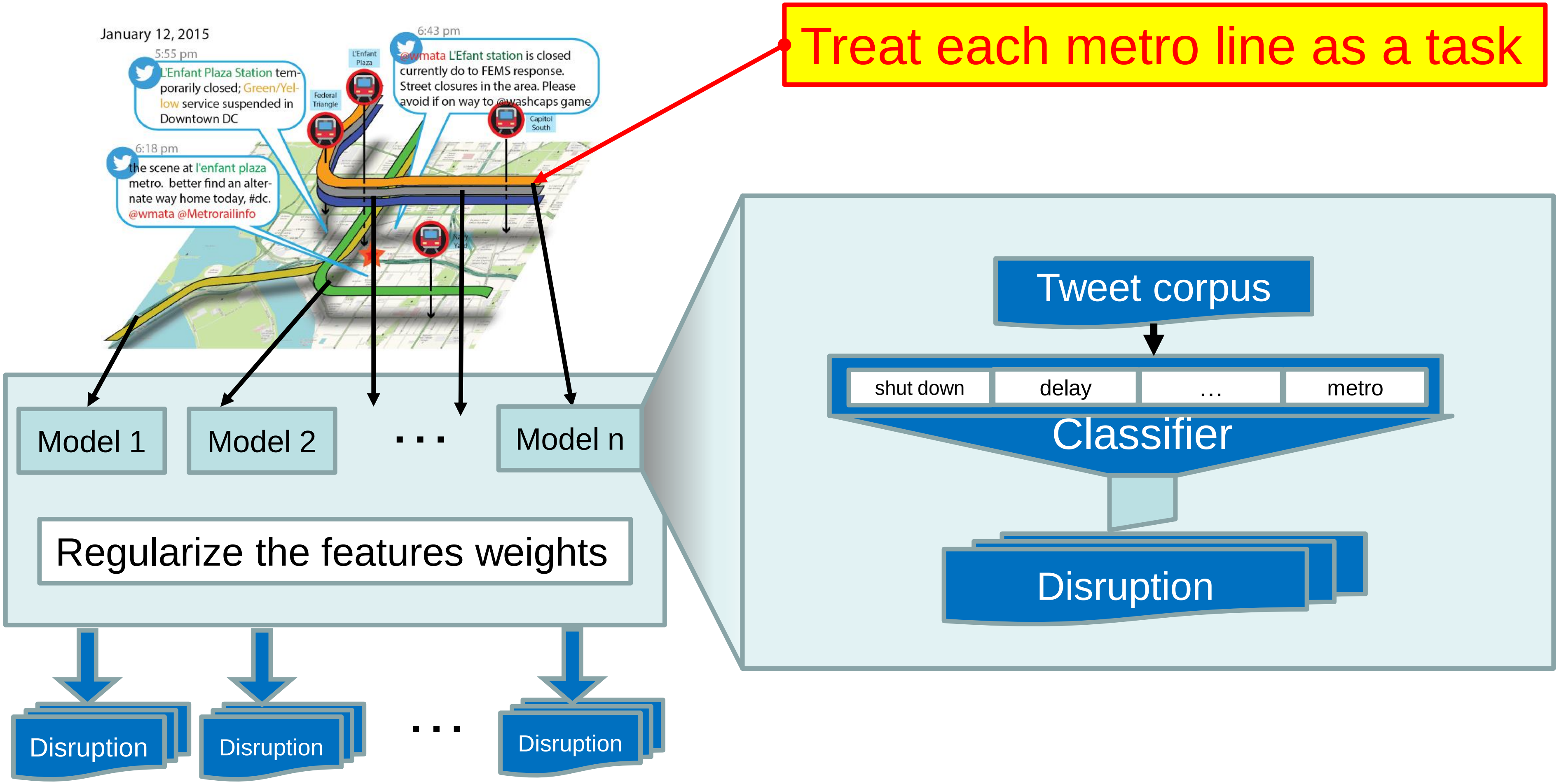
One-to-one model + One-for-all model

| One-to-one model | One-for-all model |
|---|---|
| Pro: consider the exclusive characteristics | Pro: Sufficient training data |
| Con: 1. ~~Relatedness between metro lines~~<br>2. ~~Insufficient data~~ | Con: ~~Ignore the exclusive characteristics~~ |

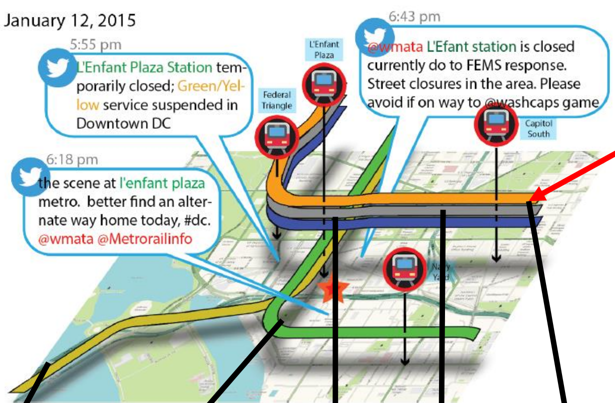
Combine

– Consider metro line's exclusive characteristics
– Consider the spatial connectivity of metro lines
– Consider the common "complaint vocabulary"
– Collect sufficient training data for each metro line

# Model Formulation



# Model Formulation




Treat each metro line as a task

Model 1

Model 2

. . .

Model n

Regularize the features weights

Disruption

Disruption

. . .

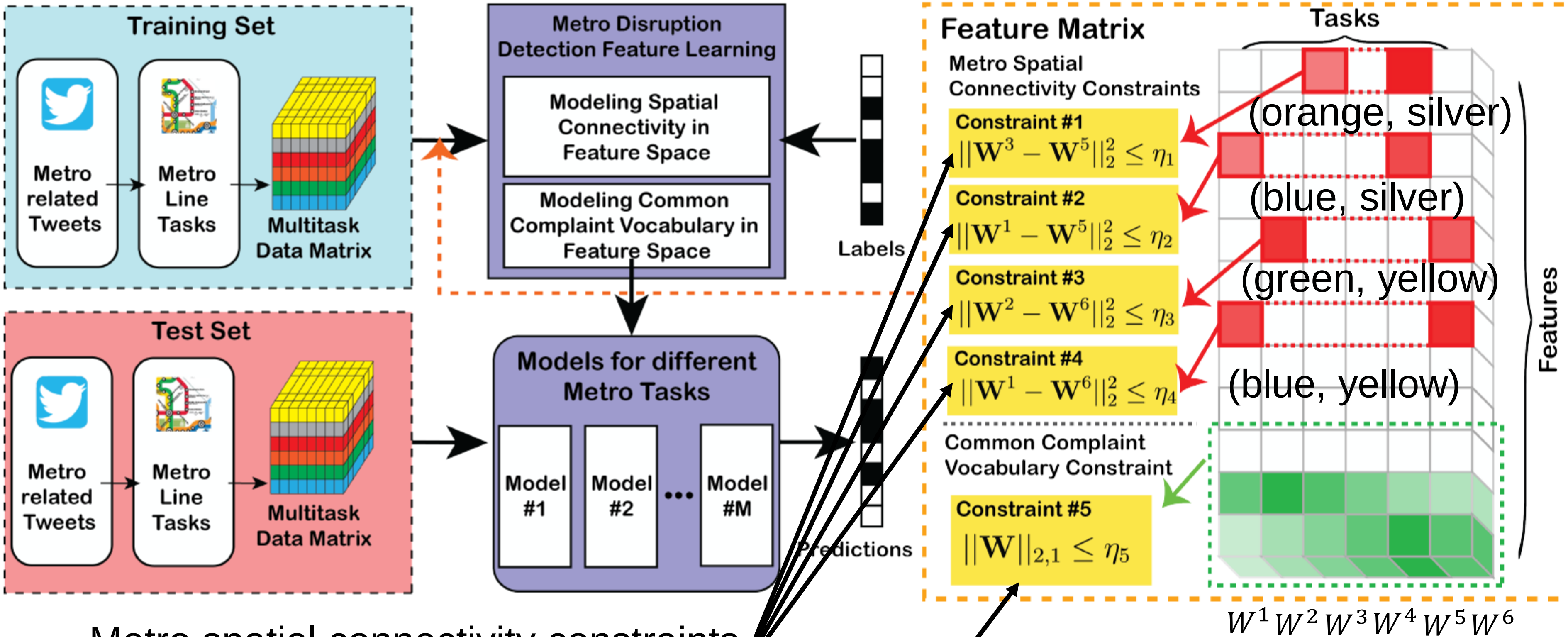
Disruption

1. Spatial connectivity of metro lines

| Metro Line | Keywords | | |
|---|---|---|---|
| Blue line | mole | interrupted | enders |
| Green line | interrupted | injury | spine |
| Orange line | spine | mouldy | safe |
| Red line | interrupted | injury | computers |
| Silver line | injury | interrupted | blister |
| Yellow line | interrupted | injury | tennant |

2. Common complaint vocabulary across metro lines

# System Workflow




- Metro spatial connectivity constraints
  - decrease differences between spatially related metro lines in feature space
- Common complaint vocabulary constraint
  - identify a core set of words most commonly used for metro service

# Proposed Model: MDDM

– Use logistic loss function

– Combine all application-specific constraints

$$\begin{aligned}
&\underset{\mathbf{W}}{\operatorname{argmin}} \sum_{c=1}^{|\Phi|} \sum_{t=1}^{m_c} \log\left(1 + \exp\{-\mathbf{Y}_t^c(\mathbf{X}_t^c \mathbf{W}^c)\}\right) \\
&\text{s.t. } \|\mathbf{W}^3 - \mathbf{W}^5\|_2^2 \le \eta_1, \|\mathbf{W}^1 - \mathbf{W}^5\|_2^2 \le \eta_2 \\
&\|\mathbf{W}^6 - \mathbf{W}^2\|_2^2 \le \eta_3, \|\mathbf{W}^1 - \mathbf{W}^6\|_2^2 \le \eta_4 \\
&\|\mathbf{W}\|_{2,1} \le \eta_5, \\
&\eta_1 \ge 0, \eta_2 \ge 0, \eta_3 \ge 0, \eta_4 \ge 0, \eta_5 \ge 0.
\end{aligned}$$

# Algorithm

multi-convex, nonsmooth problem with inequality constraints

Solution: decouple to two sub-problems (primal and dual variables)

Update primal variables

$$\mathbf{W}^{+} \leftarrow \underset{\mathbf{W}}{\operatorname{argmin}}\ \mathcal{Q} = \sum_{c=1}^{|\Phi|}\sum_{t=1}^{m_c} \log\left(1+\exp\{-\mathbf{Y}_t^c(\mathbf{X}_t^c\mathbf{W}^c)\}\right)$$
$$+\lambda_1\|\mathbf{W}^3-\mathbf{W}^5\|_2^2+\lambda_2\|\mathbf{W}^1-\mathbf{W}^5\|_2^2$$
$$+\lambda_3\|\mathbf{W}^6-\mathbf{W}^2\|_2^2+\lambda_4\|\mathbf{W}^1-\mathbf{W}^6\|_2^2$$
$$+\langle\mathbf{U}_1,\mathbf{W}-\mathbf{U}_w\rangle+\frac{\rho}{2}\|\mathbf{W}-\mathbf{U}_w\|_2^2.$$

Update dual variables

$$\mathbf{U}_w^{+} \leftarrow \operatorname{prox}_{f_1,1/\rho}(\mathbf{U}_1+\mathbf{W}),$$

# Experiments: Dataset

- Training set: Twitter data from January, 2015 to December, 2015
- Testing set: Twitter data from January, 2016 to June, 2016
- Ground truth: WMATA Daily Service Report from January 2015 to June 2016

| time | location | problem | delay (min) | full text |
|---|---|---|---|---|
| November 16, 2016 5:13 a.m. | Capitol South | a signal problem. | 8 | 5:13 a.m. A Franconia-Springfield-bound Blue Line train at Capitol South was delayed 8 minutes due to a signal problem. |
| November 16, 2016 6:04 a.m. | King St-Old Town | did not operate | 8 | 6:04 a.m. A Largo Town Center-bound Blue Line train at King St-Old Town did not operate, resulting in an 8-minute gap in service. |
| November 16, 2016 6:46 a.m. | Columbia Heights | an equipment problem | 6 | 6:46 a.m. A Greenbelt-bound Green Line train at Columbia Heights was offloaded due to an equipment problem. Passengers experienced a 6-minute delay. |

# Experiments: Features

- Sentiment features for Twitter (StaticTwitterSent)
  - Remove non-English words
  - Remove hastags and usernames
  - Remove single letter words, and numbers
  - Remove stopwords defined by NLTK
  - Remove words with frequency less than 10
  - Remove words which never appear in the metro-related tweets

TOP 3 MOST FREQUENT WORDS FOR EACH METRO LINE.

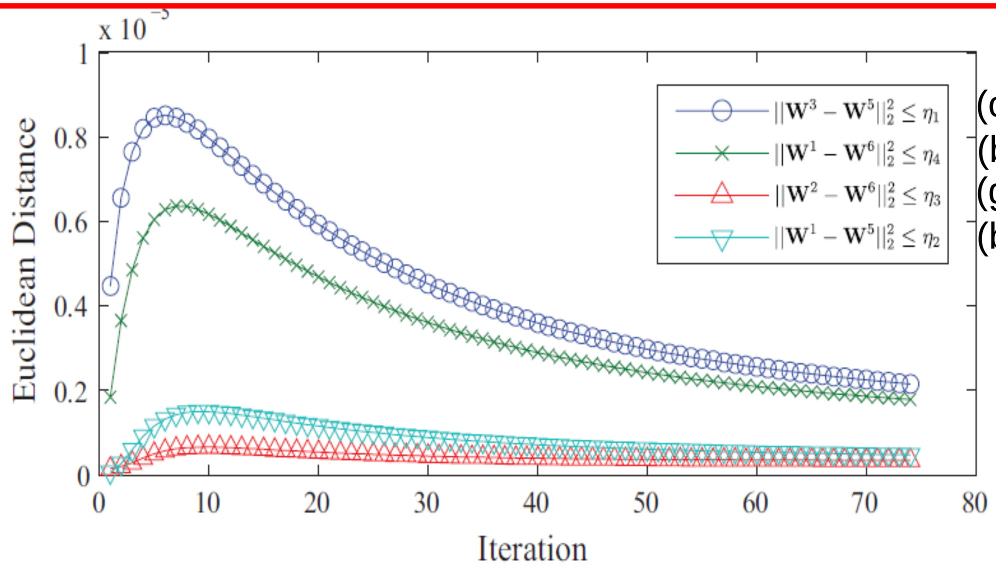
| Metro Line | | Keywords | |
|---|---|---|---|
| **Blue line** | mole | interrupted | enders |
| **Green line** | interrupted | injury | spine |
| **Orange line** | spine | mouldy | safe |
| **Red line** | interrupted | injury | computers |
| **Silver line** | injury | interrupted | blister |
| **Yellow line** | interrupted | injury | tennant |

# Event Prediction Performance

- MDDM outperforms other models on 5 metro lines on F-measure.

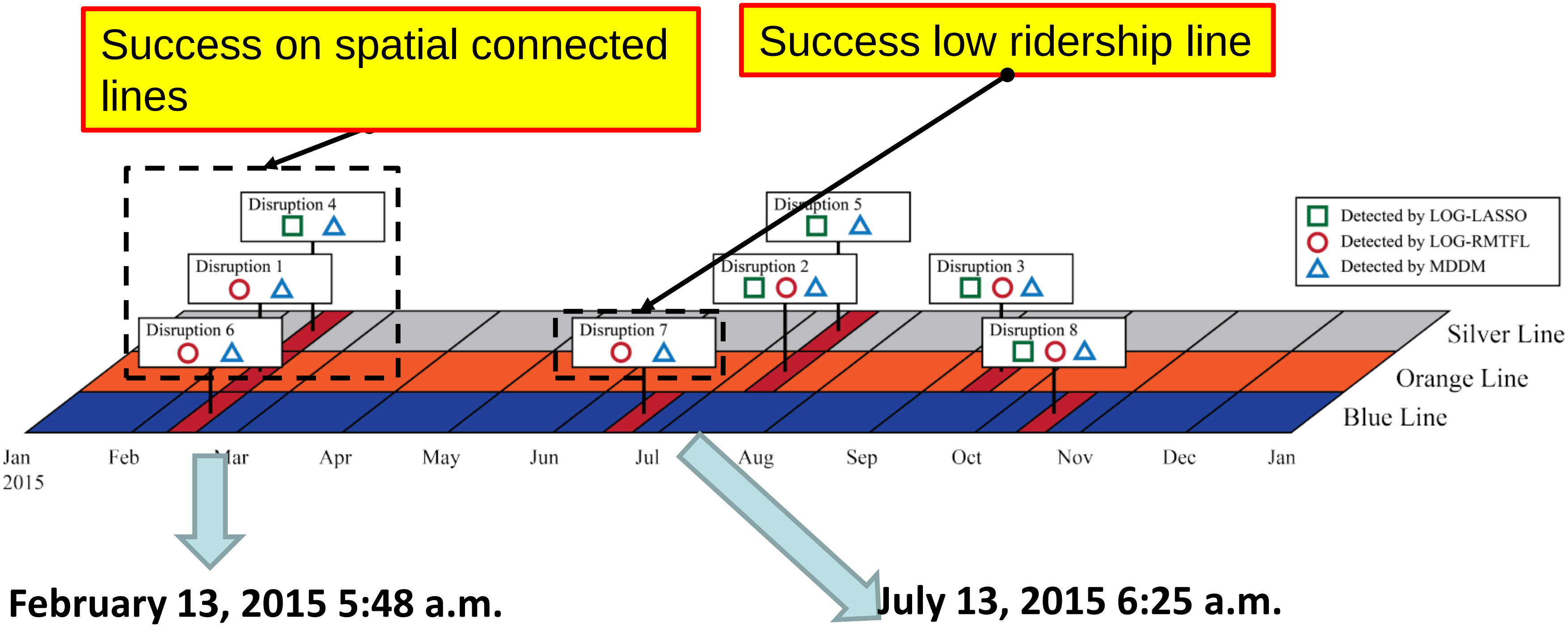
| Method | Blue | Green | Orange | Red | Silver | Yellow |
|---|---|---|---|---|---|---|
| LOGR | 0.37 | 0.48 | 0.56 | 0.63 | 0.49 | 0.40 |
| LOG-LASSO | 0.42 | 0.50 | 0.56 | 0.67 | 0.49 | **0.43** |
| LOG-RMTFL | 0.35 | 0.52 | 0.59 | 0.68 | 0.49 | 0.39 |
| MDDM | **0.44** | **0.55** | **0.63** | **0.69** | **0.52** | 0.40 |

- MDDM encourages spatial related metro lines to be similar.




(orange, silver)
(blue, silver)
(green, yellow)
(blue, yellow)

# Case Study




**February 13, 2015 5:48 a.m.**

A train at **McPherson Square** was offloaded due to a brake problem. Passengers experienced a 12-minute delay.

**July 13, 2015 6:25 a.m.**

A train at **Pentagon City** was offloaded due to a brake problem. Passengers experienced an 8-minute delay.

# Summary

- Formulate a multi-task learning framework for metro disruption detection using online social media
- Model semantic similarity among metro lines in feature space
  - Spatial connectivity
  - Common complaint vocabulary
- Develop an efficient algorithm to solve the proposed model
  - Update primal variables
  - Update dual variables
- Conduct extensive experiments to validate the effectiveness and efficiency of the proposed model

# Future Work

- Multi-resolution transit service disruption detection
  - Metro line level
  - Metro station level
- Multi-view transit service disruption detection
  - New York metro system
  - Washington, D.C. metro system
- Spatial-temporal transit service disruption detection
  - Spatial connectivity across metro lines
  - Temporal relatedness between events
  - Rush hours and non-rush hours

# Thank You

The code and slides are available at

**https://github.com/TaoranJ/wmata_service_diruption_detection**

Welcome any related questions and suggestions.