

# AVERAGED GRAPH ANALYSIS AND FAILURE RESILIENCE OF A PUBLIC TRANSPORT NETWORK



**Authors:**

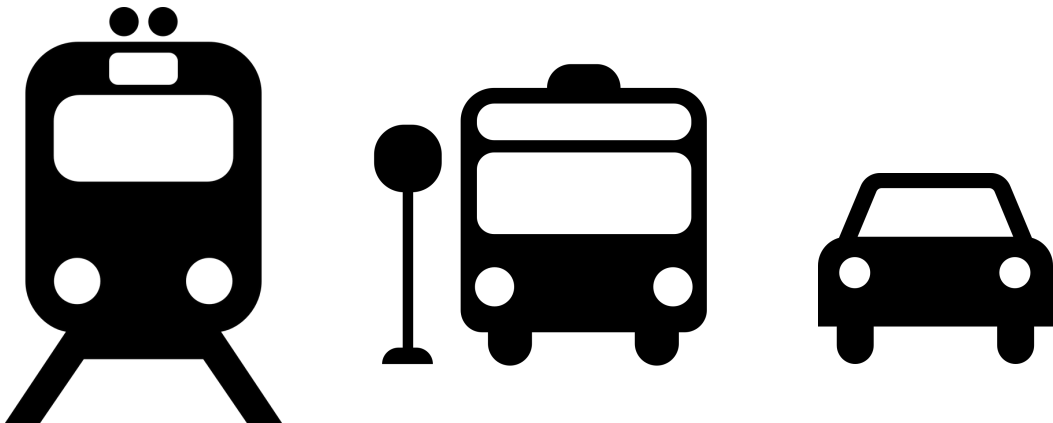
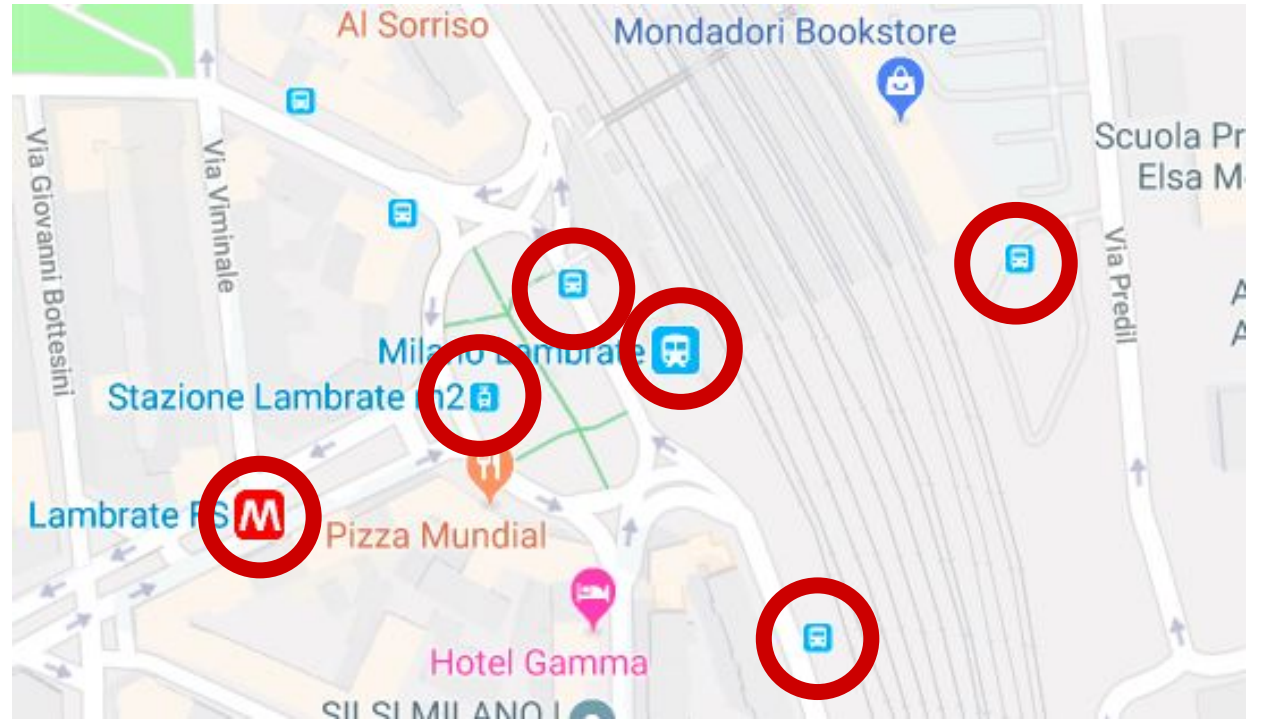
Nassim Habbash

Ricardo Anibal Aragon Matamoros

# Problems

- Transportation networks can be **disjoint**
- Transportation datasets might **not** be **standardized**
- How to correctly **represent** a network of a set of different means of transportation, possibly disjoint and not conforming to a standard?

All the circled stops service the zone of **Lambrate**, but each one is used by **different lines** and has **different coordinates**. This can pose some issues in the zone analysis.



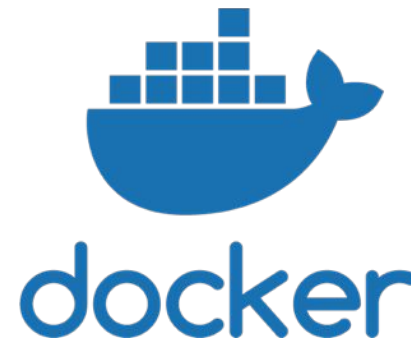
Different means of transportation, possibly coming from **different** datasets, might not be standardized nor coherent with each other

# Dataset

The **dataset** used in this project is Milan's AMAT GTFS feed, consisting of the feed of every ATM service in March 2019.

The data was obtained from **TransitFeeds**.

A **Docker container** has been setup for ease of reuse and multiple operability, to extract from a PSQL **database** a graph of **bus lines**, **tram lines** and **metro lines** of Milan.



# What are average graphs?

**Average graphs** represent an averaged union of all the distinct networks considered through an operation defined as **spatial clustering**.

This operation allows us to generate graphs that represent the **spatial connectivity** of different regions (clusters) of the analyzed macro-area, based on the location of **every stop** of **every graph**.

*Demo: Average Graphs section,  
Neighbor Graph section*

Given a set of seed points (the actual stops of every network), we group them together in **regions** if their **haversine distance** is minor or equal of a parameter  **$\gamma$** .

This parameter represents the **clustering radius** of a region.

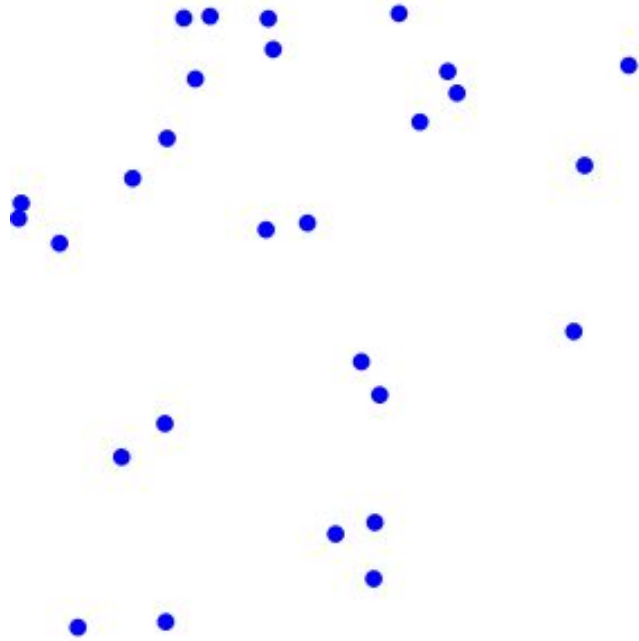
The **centroid** of each region is iteratively computed as the **mean** of its stop's coordinates.

From the resulting regions, we are able to compute the **Voronoi Diagram**, representing the spatial relation between regions, and its complement, the **Delaunay Triangulation**.

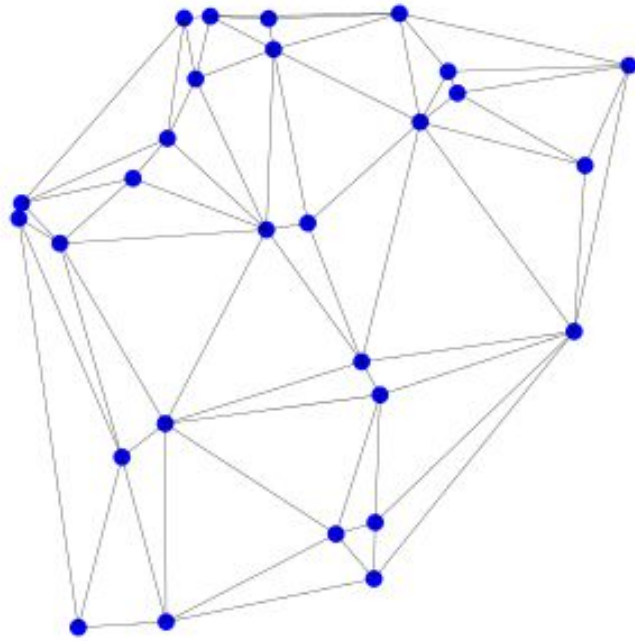
We'll call the Delaunay Triangulation graph the **Neighbor Graph**, and we introduce a parameter,  **$\rho$** , that represents the **maximum distance** allowed **between two neighboring regions**.

*Demo: Average Graphs section,  
Neighbor Graph section*

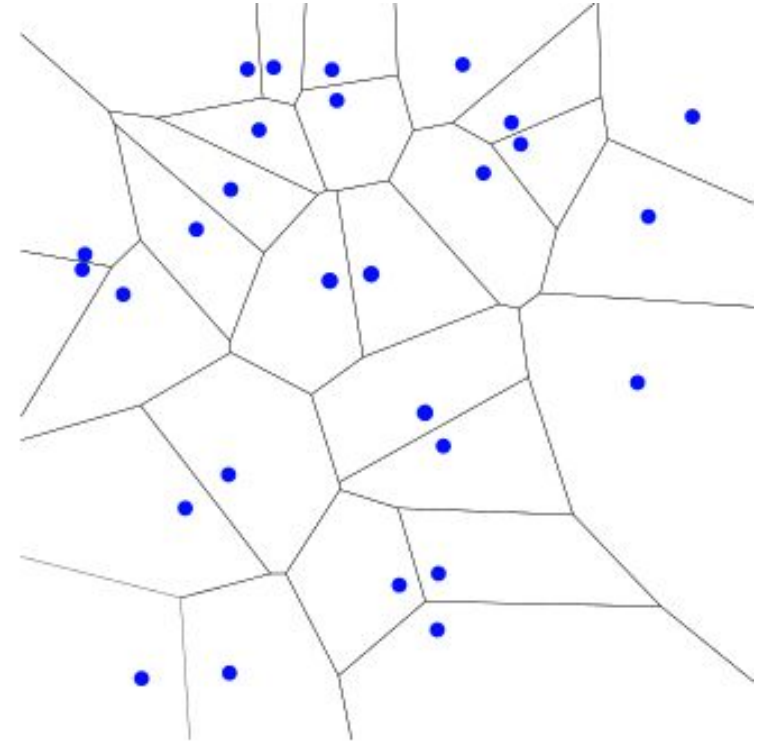
- Spatial clustering -



Centroid of every region generated  
by the spatial clustering algorithm



Delaunay triangulation, representing  
the **neighboring relationship between  
regions**



Voronoi diagram, representing the  
**spatial subdivision of each  
region's influence area**

From the **neighbor graph**, we go on to compute the **cell-to-cell flow graph**.

We define cell-to-cell flow as a flow indicating the presence of a **direct link** between **stops** in two **neighboring** regions.

The cell-to-cell flow graph and the neighbor graph, **share** the same **nodes**, but **do not share** the same **edges**.

The cell-to-cell graph represents **how** a public transportation **serves** a macro-area on a **topological level**.



# Comparison

A **comparison** between the neighbor graph and the cell-to-cell flow graph allows us to analyze **how well** the public services **serve** regions of given parameters  $\gamma$  and  $\rho$ .

**Some questions that we could ask are:**

- How is the periphery of the city served?
- How well interconnected are different regions of the city?
- Are there many regions that act as “gateways” - and could hence be more prone to intense traffic?

# Network resilience to attacks

We analyzed how well could the cell-to-cell graph **withstand** different **attack strategies**.

The strategy are measured against the graph's Giant Component size, and test **how long** it takes to reach its **percolation threshold**.

## This allows us to observe:

- How area-of-effect attacks can damage the network.
- How the original networks are affected.
- How different micro and macroregions (by varying  $\gamma$ ) are affected by different strategies.

# Conclusions

- Average graphs allow us to analyze network data under different **standards** and **not completely jointed**
- The average graphs generated in this project pertain to the **topology** of the network, but **temporal** average graphs can also be generated
- Milan's transport network offers good connectivity for **central** and **north-western** regions of the city, but still does not effectively connect the **periphery**
- Smart attack scenario need in average **15 attacks** to render the network useless

# Thanks for your attention

Bibliography