URBAN-GEO BIG DATA

Analysis of the Floating Car Data of Turin Public Transportation system

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Introduction

- The largest part of **movements** in an **urban environment** is constrained to the **road network**
- In the field of transportation, **GNSS data** collected from **vehicles** are frequently referred as **Floating Car Data** (**FCD**)
- **FCD** are **Urban Geo Big Data** and contain the key information for estimating traffic **impedance maps**, potentially in real-time

Aim of the work

To develop a reliable **methodology** able to perform the preliminary analyses needed for computing the **impedance maps from FCD**

- **management** and **visualization** of a **huge data amount**
- preliminary tests for **projecting** the **raw FCD** to the **route lines**

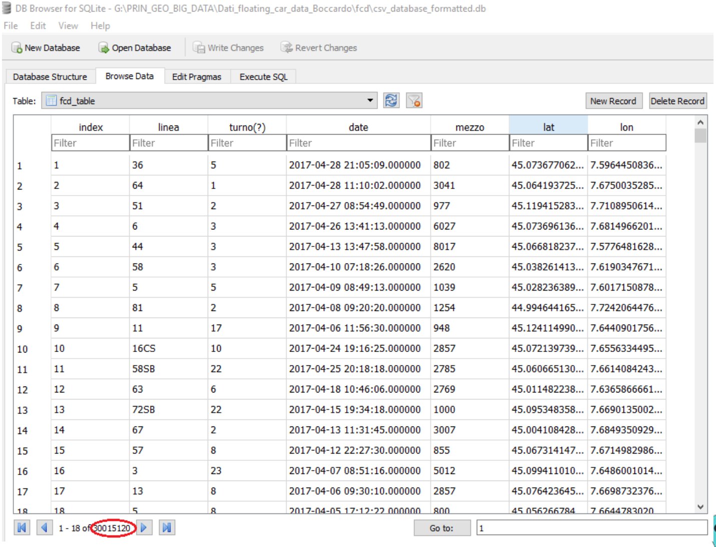
Features of the analysed FCD

The analysed **FCD**:

- acquired in the month of April 2017 by the on board units installed on the vehicles of the **Turin Public Transportation** company (Gruppo Torinese Trasporti - GTT)
- include the pairs of WGS84 **geographical coordinates** (longitude, latitude) along with a **set of attributes** (vehicle code, line code, turn, timestamp, ecc.)
  - variable acquisition rate (from few to tens of seconds)
- provided in the **CSV** format
  - the original file is very **heavy** (2.19 GB)
  - converted in a **database** through a `Python` script based on the `sqlite3` and `pandas` libraries

Database generation

About **30·000·000** records!



	index	linea	turno(?)	date	mezzo	lat	lon
1	1	36	5	2017-04-28 21:05:09.000000	802	45.073677062...	7.5964450836...
2	2	64	1	2017-04-28 11:10:02.000000	3041	45.064193725...	7.6750035285...
3	3	51	2	2017-04-27 08:54:49.000000	977	45.119415283...	7.7108950614...
4	4	6	3	2017-04-26 13:41:13.000000	6027	45.073696136...	7.6814966201...
5	5	44	3	2017-04-13 13:47:58.000000	8017	45.066818237...	7.5776481628...
6	6	58	3	2017-04-10 07:18:26.000000	2620	45.038261413...	7.6190347671...
7	7	5	5	2017-04-09 08:49:13.000000	1039	45.028236389...	7.6017150878...
8	8	81	2	2017-04-08 09:20:20.000000	1254	44.994644165...	7.7242064476...
9	9	11	17	2017-04-06 11:56:30.000000	948	45.124114990...	7.6440901756...
10	10	16CS	10	2017-04-24 19:16:25.000000	2857	45.072139739...	7.6556334495...
11	11	58SB	22	2017-04-25 20:18:18.000000	2785	45.060665130...	7.6614084243...
12	12	63	6	2017-04-18 10:46:06.000000	2769	45.011482238...	7.6365866661...
13	13	72SB	22	2017-04-15 19:34:18.000000	1000	45.095348358...	7.6690135002...
14	14	67	2	2017-04-13 11:31:45.000000	3007	45.004108428...	7.6849350929...
15	15	57	8	2017-04-12 22:27:30.000000	855	45.067314147...	7.6714982986...
16	16	3	23	2017-04-07 08:51:16.000000	5012	45.099411010...	7.6486001014...
17	17	13	8	2017-04-06 09:30:10.000000	2857	45.076423645...	7.6698732376...
18	18	5	8	2017-04-05 17:12:22.000000	800	45.056266784	7.6644783020

Velocity analysis

- The **FCD** were **organized** for **lines**, then for **vehicles** and finally they were **chronologically ordered**

- For every line of the transportation network:
  - the *Vincenty* formula was used to compute the **planimetric displacement** Δs between **two positions** of the specific vehicle in two **consecutive time moments**
  - the **velocities** were computed as $v = \dfrac{\Delta s}{\Delta t}$

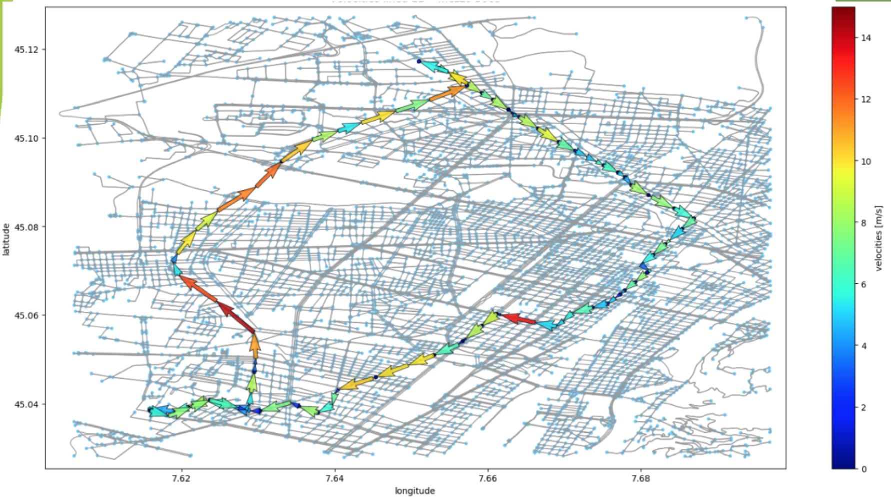
Velocity analysis

- The computed **velocities** were represented as **arrows** and plotted on top of the Turin drive network graph, automatically downloaded from Open Street Map through the `OSMnx` Python library

```
def boh(drive_network_graph, start_lon, start_lat, delta_lon, delta_lat, velocities, sogli
    fig_from_function, ax_from_function = ox.plot_graph(drive_network_graph, close = False
    nz = mcolors.Normalize(vmin = soglia_inf, vmax = soglia_sup)
    #plt.gca().set_aspect('equal', adjustable='box')
    plt.quiver( start_lon, # start x
                start_lat, # start y
                delta_lon, # delta x
                delta_lat, # delta y
                angles='xy', # 'xy': arrows point from (x,y) to (x+dx, y+dy). Use this for
                scale=1, # più è grande, + le frecce sono corte Number of data units per a
                scale_units='xy', # usando le scale units, non è più necessario alterare l
                color=cm.jet(nz(velocities)),# color = velocities
                zorder = 5, #più è alto, più il plot è in primo piano
                edgecolor='k', # colore bordo freccia
                linewidth=.7,
                alpha=0.8) # trasparenza
```

Example of computed velocities

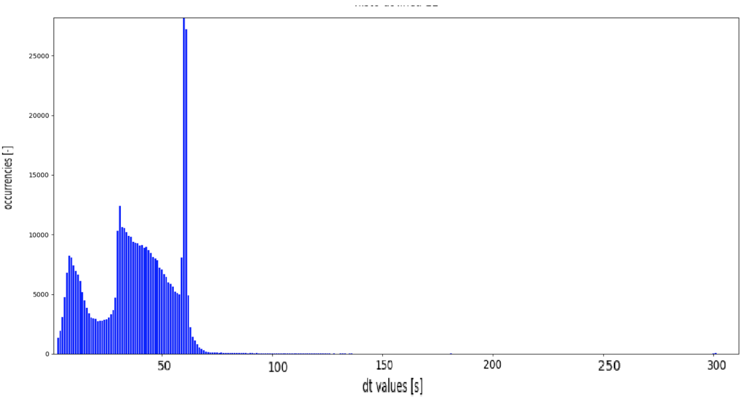
Line 11, vehicle 3063



Outlier removal

Before proceeding with the time analysis, the **outliers** were **removed** by eliminating all the records:

1. whose Δt are higher than 99.5^{th} percentile and lower than 0.5^{th} (statistically not significant)
2. characterized by a velocity higher than 5 times the mean



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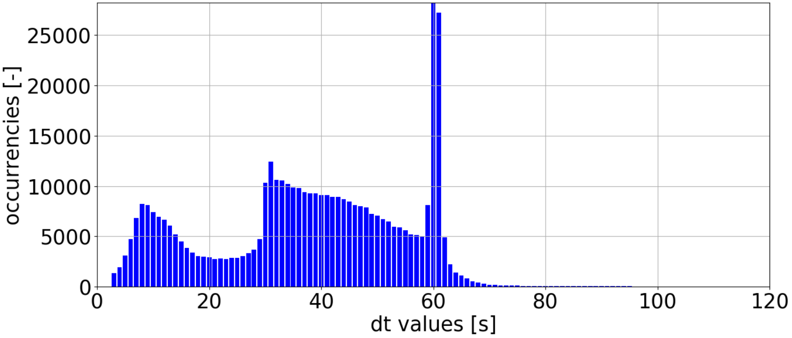
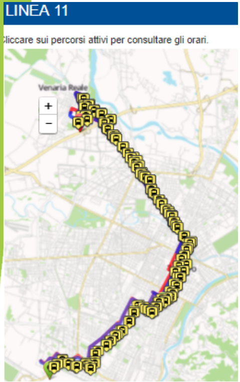
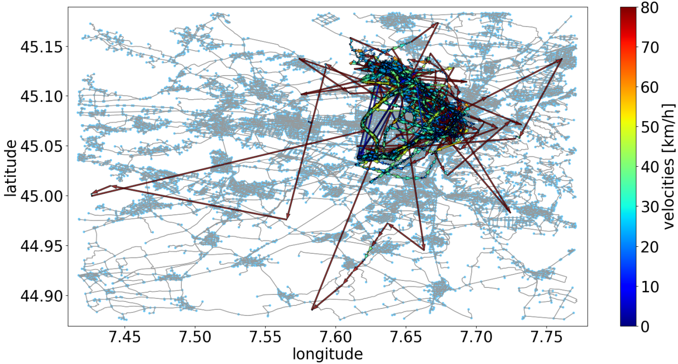


Line 11: velocities

After the **outlier removal**, the reconstructed path follows more closely the actual line route: the **longest arrows**, probably due to the bus routes from and to the depot, are **eliminated**





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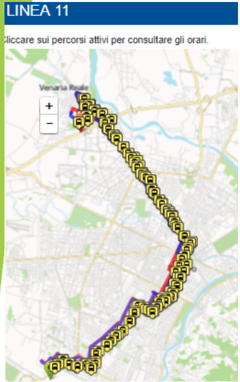
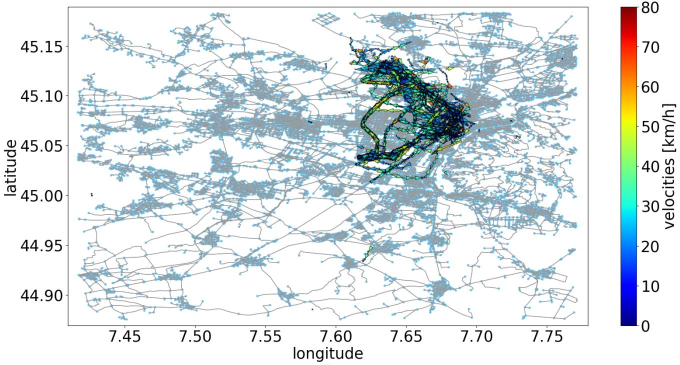
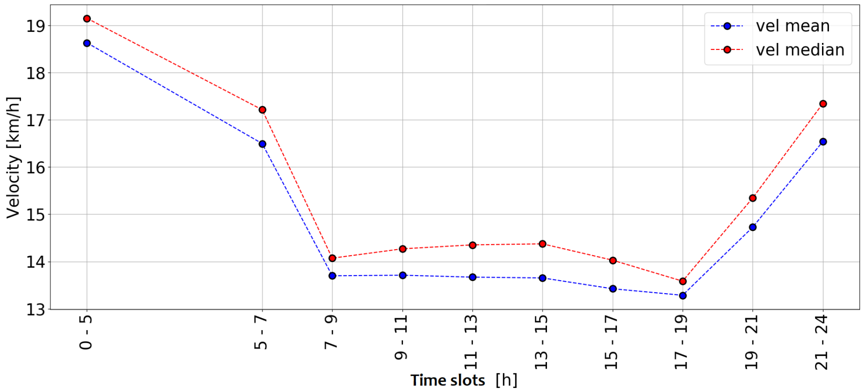




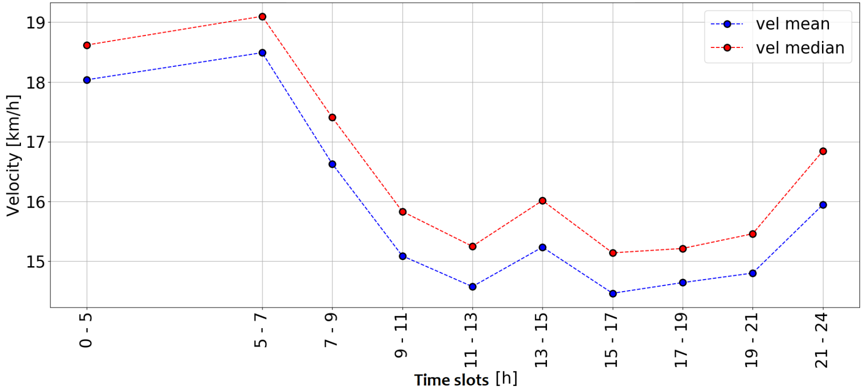
Temporal analysis

- Once the outliers were removed, a **temporal analysis** was performed
- The data were divided into **working** and **weekend days**, considering the following **time intervals** during the day:
  - 0 - 5
  - 5 - 7
  - 7 - 9
  - 9 - 11
  - 11 - 13
  - 13 - 15
  - 15 - 17
  - 17 - 19
  - 19 - 21
  - 21 - 24

Line 11: time slot velocities in working days



Line 11: time slot velocities in weekend days



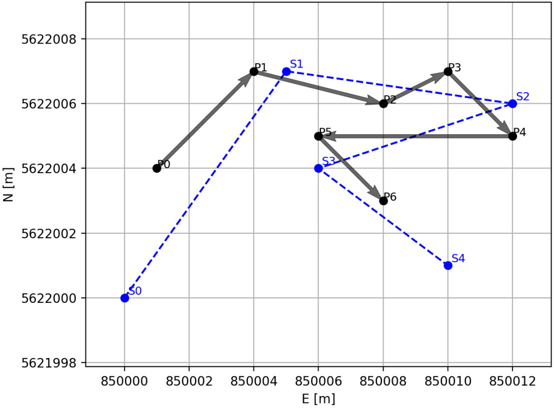
Considerations

- The **highest velocities** occur at **night** and in **late evening**, with a **local peak** shortly after the **lunch hour**
- The **lowest velocities** occur during the **peak hours**, in correspondence of the **office entrance** and **exit hours**
- The differences between **working** and **weekend days** are more **evident** in the **peak hour** time slots
- During the **0-5** and **21-24** time slots, the **difference** is **small**, since in these hours the **traffic** level is low also in the **working days**

FCD projection to line networks

A preliminary strategy was implemented to **assign** the **velocities to** the **line network topology**:

- for **every FCD point**, the **closest tree** of the specific line network is selected



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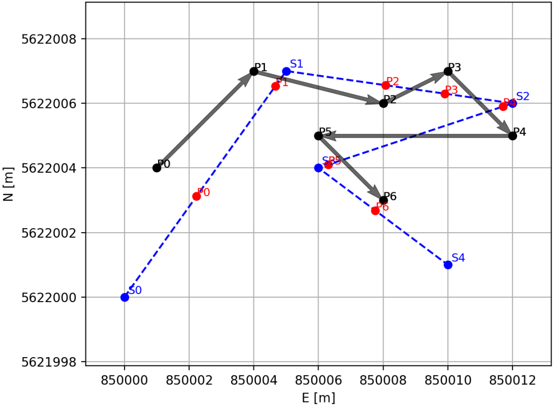

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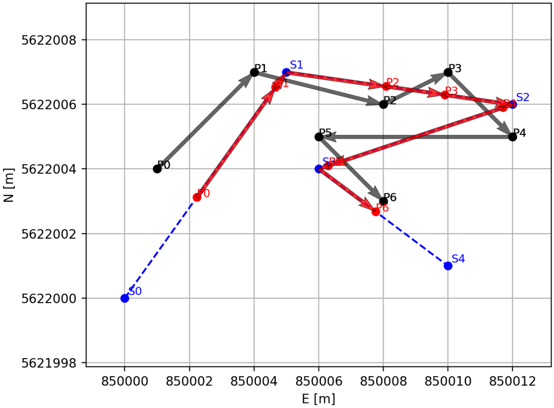

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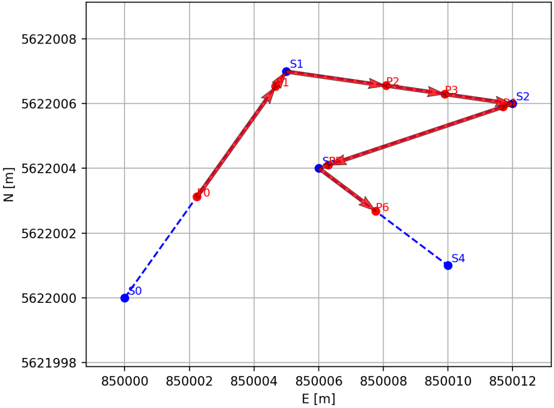
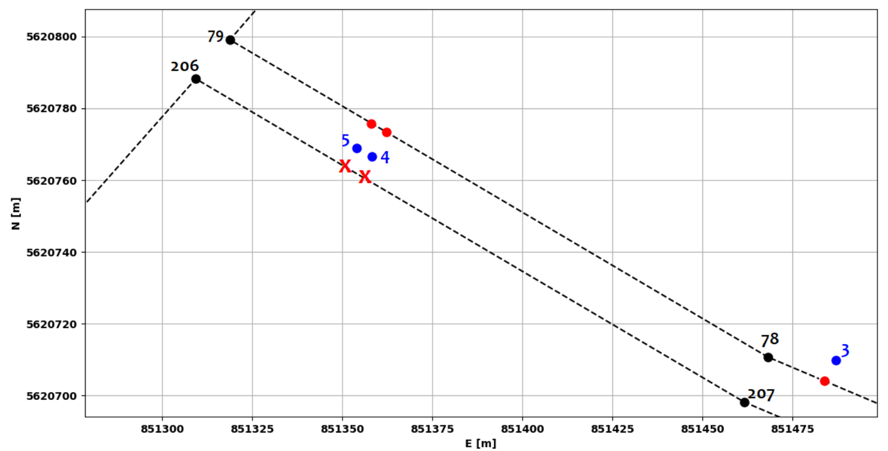


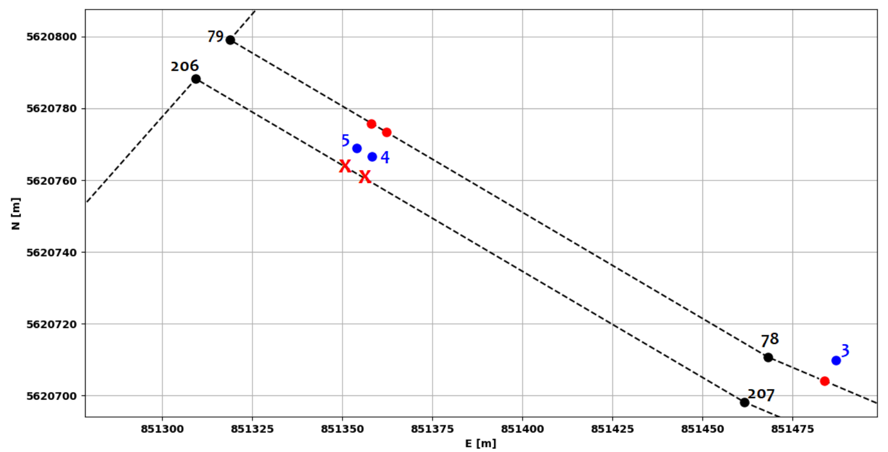
Topological issues

Topological issues occur when the FCD point is located in a segment in which the **distance between two** (or more) **arcs** is **comparable** to the **GNSS measurement errors**



Topological issues

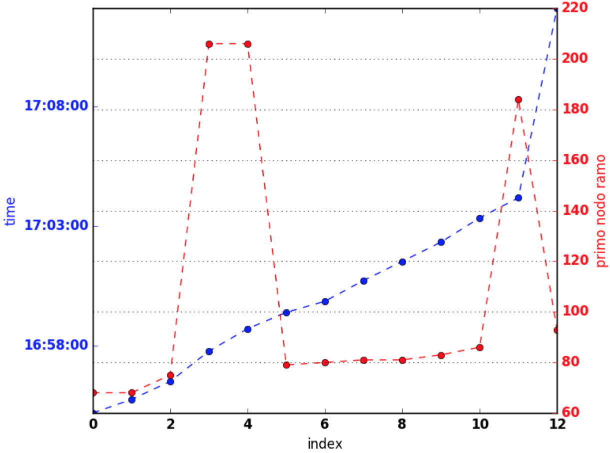
It is rather improbable that the FCD **point 4** and **point 5** may be assigned to the **tree 206-207** of the network, since the vehicle was located in the **tree 77-78** few moments before



Topological issues

A possible solution is to consider:

- the **temporal information** contained in the **FCD**
- the **cardinality information** contained in the **line network**



Select the segment closest to the previous selected tree

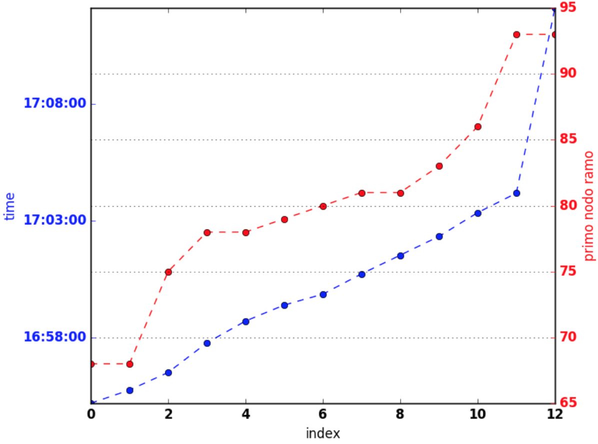
Projection algorithm

The **assignment errors** can be identified considering that:

1. the bus cannot travel back in time $t_{i+1} > t_i$
2. the bus cannot travel big distances in a short time interval $nodo_{t+1} < nodo_t + 20$
3. the bus cannot move in the wrong direction: $node_{t+1} > node_t$ (possible problem when a new lap begins)

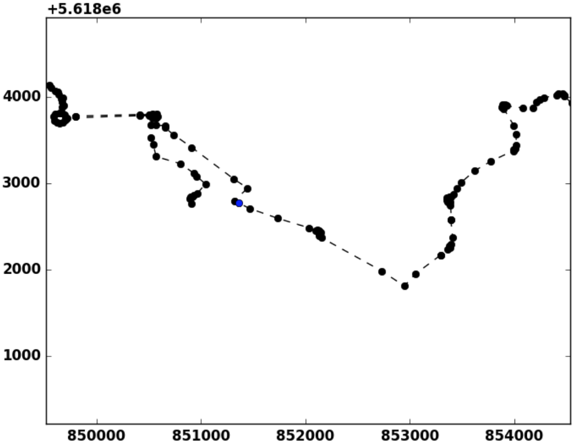
Projection algorithm

The **temporal trend** of the **node IDs** must be **constant** or **increasing** with small slopes (constant or positive derivative)



Projection algorithm: error removal

For every projected point, if the **ipothesis number 2** is **not verified**, the **arc** incorrectly selected is **removed** from the network together with the **following arcs** and the projection is newly performed



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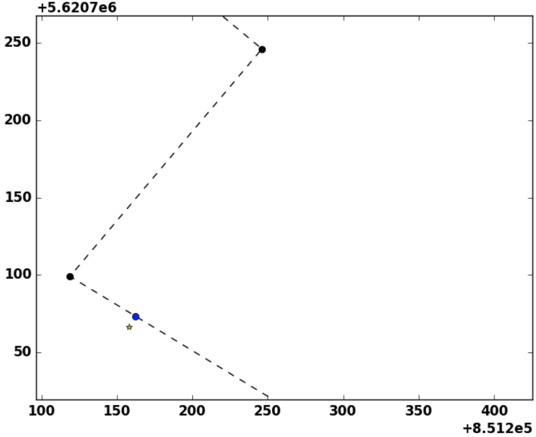
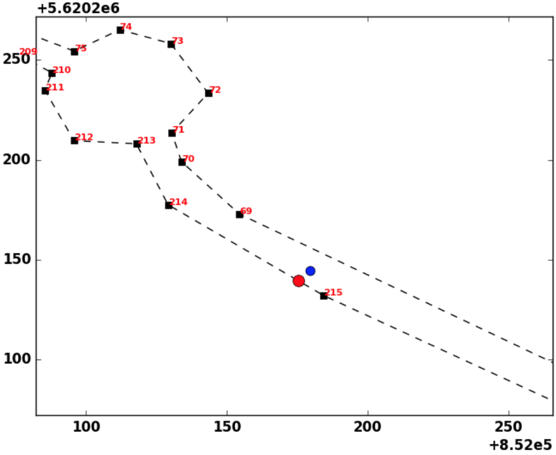


Projection algorithm: error removal

For every projected point, if the **ipothesis number 3** is not verified, the **arc** incorrectly selected is **removed** from the network together with the **previous arcs** and the projection is newly performed



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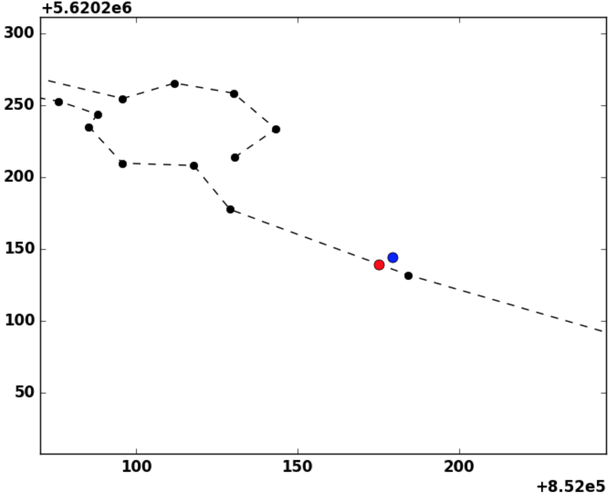
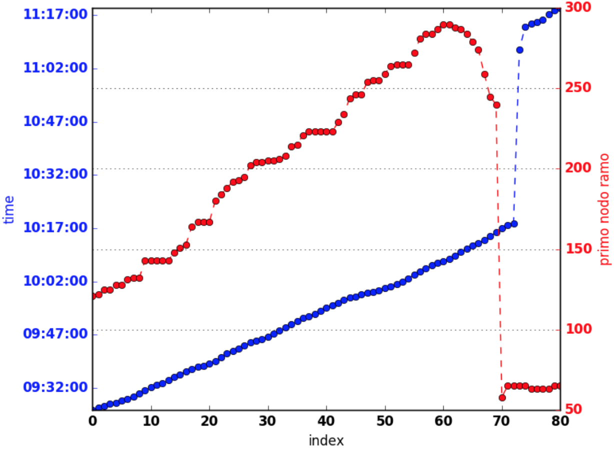


Identification of a new lap

- A **new lap** can be identified on the basis of a **peak** in the trend of the **node IDs**
- Once the last point of the lap is identified, the following point are newly projected forcing the algorithm to consider only nodes with low values of IDs



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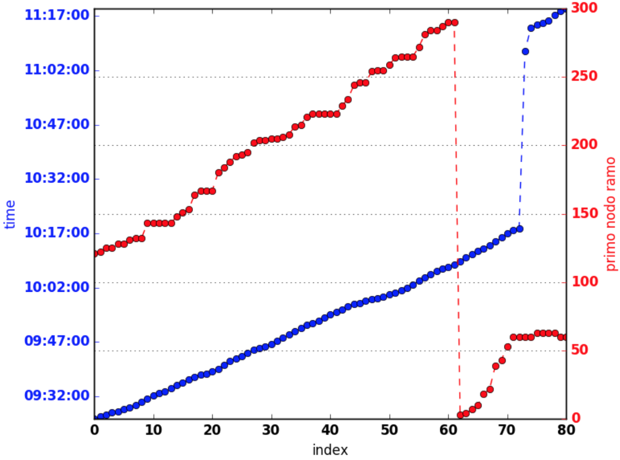

Results

- The designed and implemented algorithm is quite effective
- Few assignement errors still remain, nevertheless a solution has already been designed and is under implementation

Problem in visually validating such huge amount of data

Conclusions

- A **first strategy** to analyse the **FCD** of the Turin Public Transportation system was implemented, in view of an automatic and possible real-time impedance map generation
- A **huge amount** of **FCD** were processed to compute the **vehicles velocities**
- A **visualization** approach based on Osmnx library was adopted
- A preliminary **temporal analysis** was carried out
- A method to **assign** the **velocities** to the line **network topology** was developed and successfully tested

Further developments

- To refine the outlier removal process in order to all the **velocities not referable** to the **actual path** of the **lines**
- To **test** the developed **topological procedure** on **all** the **velocity data**, by checking the **effective reliability** and **real-time feasibility** of the designed methodology
- To **compute** the **impedence maps** and deliver the corresponding **metadata**
- To extend the developed methodology to other cities

Thank you for your kind attention!

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