User-based representation of time-resolved multimodal public transportation networks

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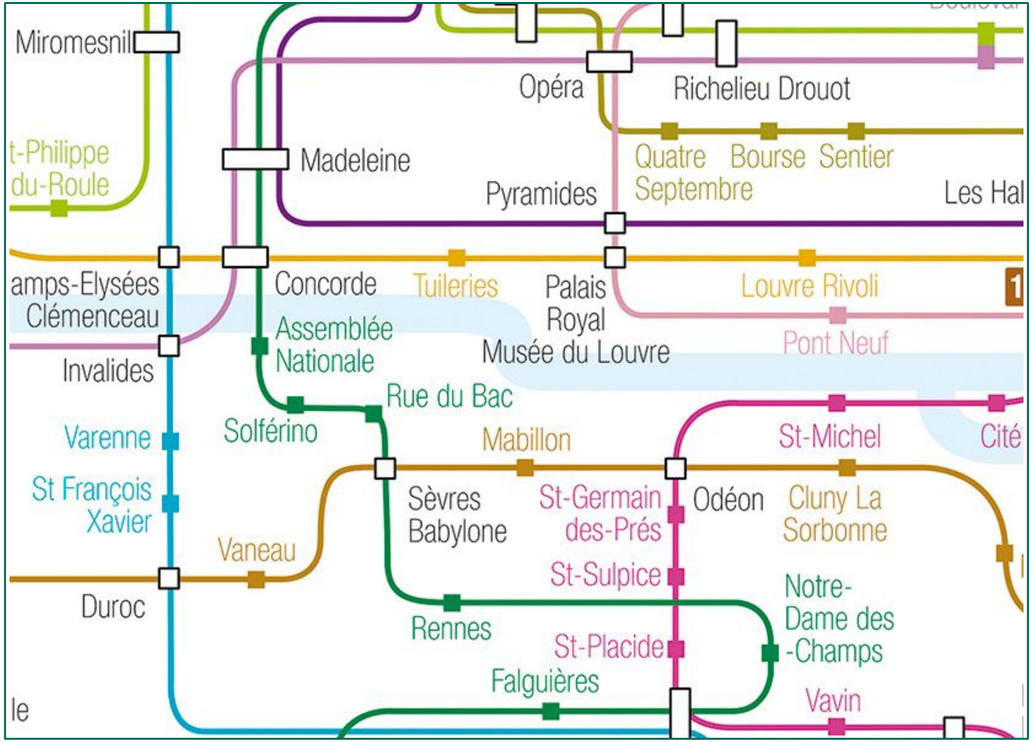
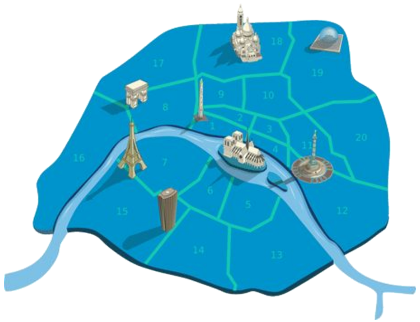
Straightforward representation



Urban transportation network properties



spatially embedded

multimodal

time-resolved

Outline

New representation including time information

Identify hidden patterns of priviledged connections

Quantify overall efficiency for commuting flow

Overall aim : characterize different cities in the same framework

Urban transportation data

General Transit Feed Specification

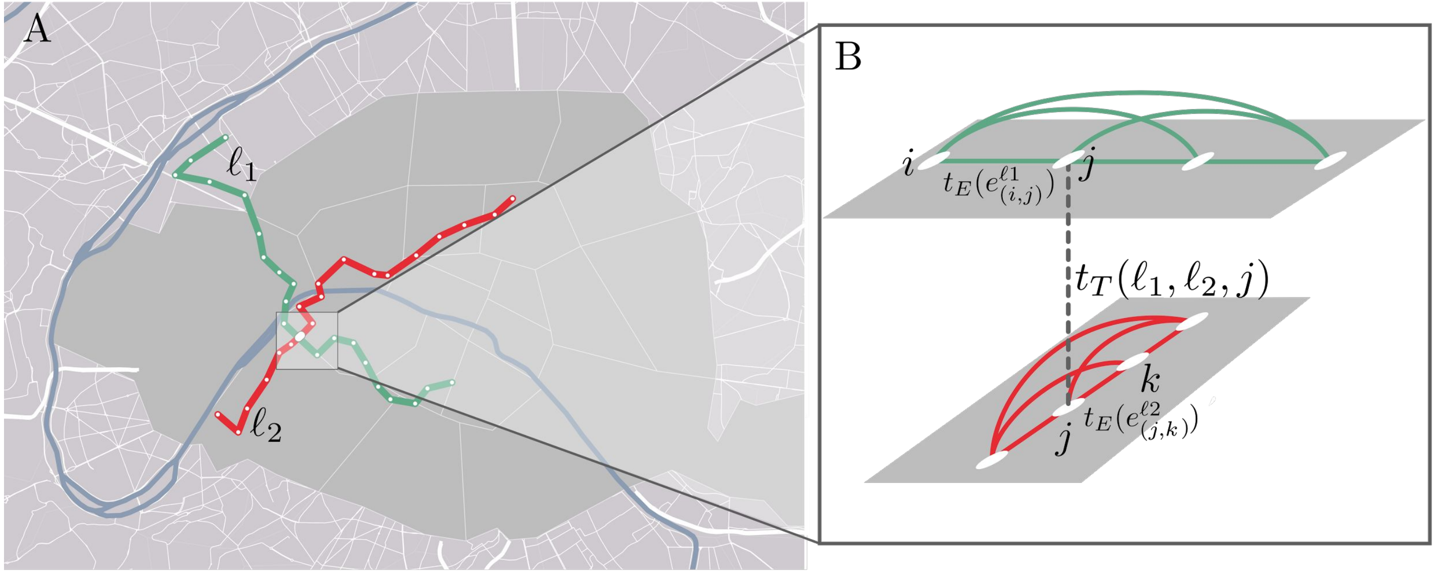
geospatial information

&

schedule information

Transportation network representation

multi-edge & P-space



Public transportation vs car

Choice criteria:

1. total travel time
2. variability in the total travel time
3. number of transfers

Uncovering fast connections

Choice of a typical day: focus on commuting hours

Multi-edge P-space representation:

1. Weights $\leftarrow$ time spent in the transportation mean

   $+$ waiting time

2. Penalties: transfer times

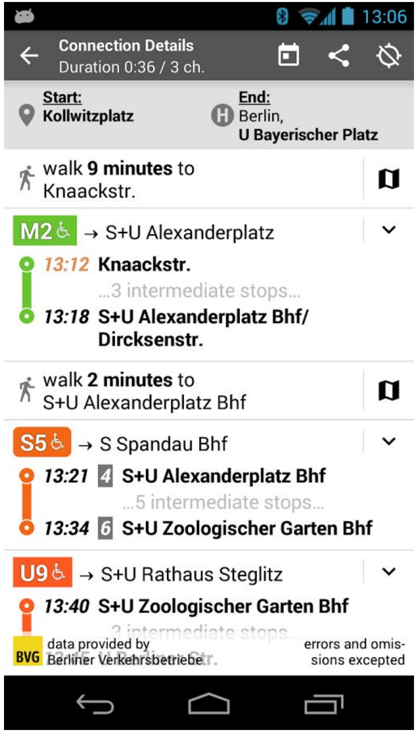
Uncovering efficient transportation connections

Adaptation of Dijkstra's algorithm

⟶ Computation of the shortest path in time

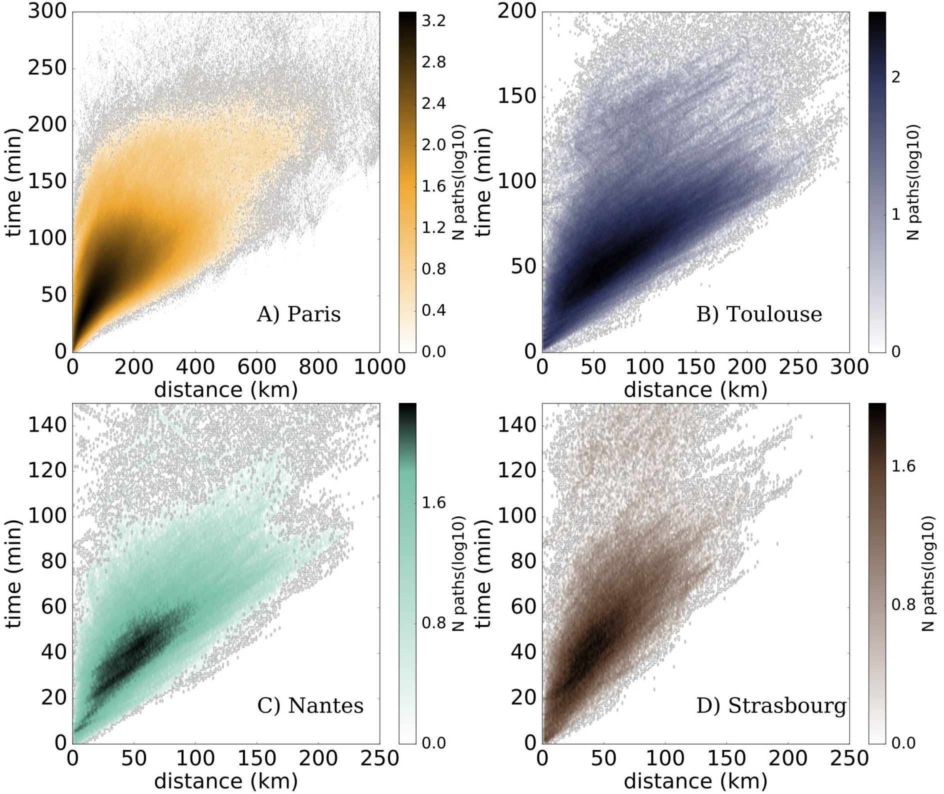
for any origin-destination pair

# of transfers limited



screenshot taken from Offi - Journey Planner

Shortest time paths



For each (origin,destination)

commuting time
vs
geographical distance

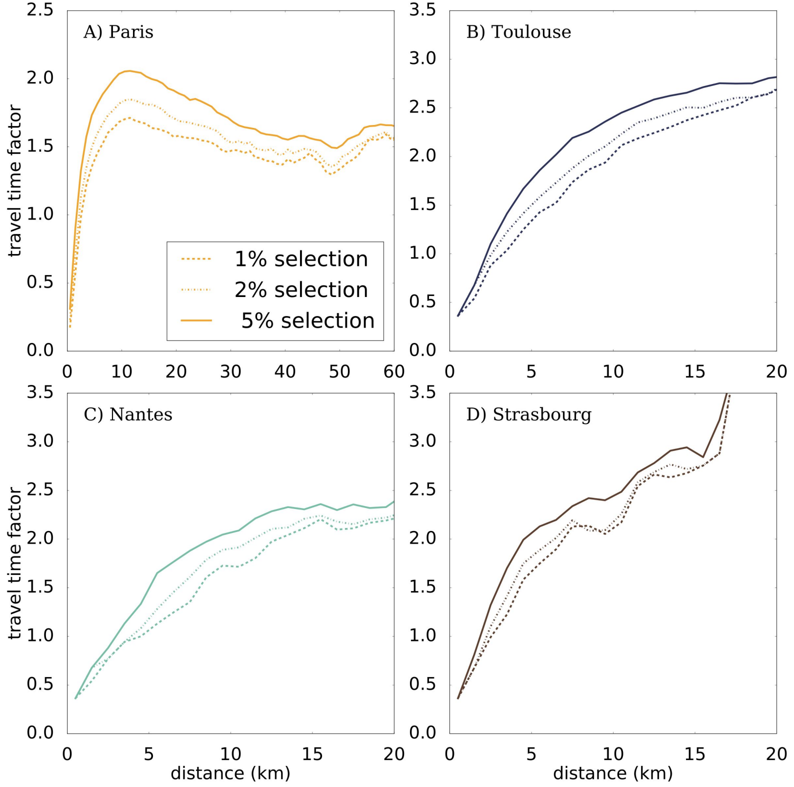
Car commuting times

Extracted from the French national survey of transport and mobility 2007-2008

- distance travelled (1 Km resolution), by
- transportation mean used & trip duration (1 min resolution)

Typical time needed to commute a particular distance by car : median of the distribution of times over the entire sample

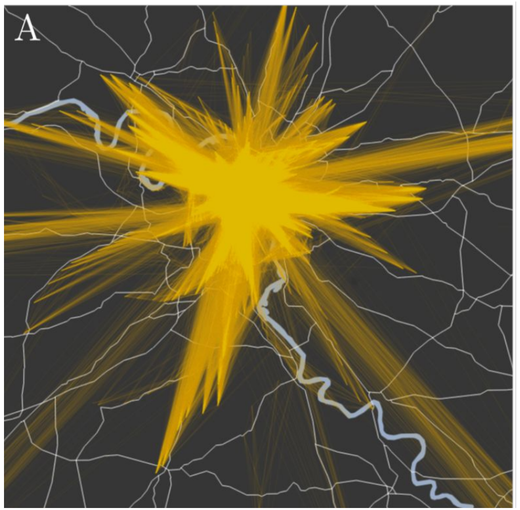
Travel time factors



For each distance:

$$\frac{\text{Public transportation commuting times}}{\text{Car commuting times}}$$

Privileged connections



The structural properties of the transportation network are geographically constrained

Going beyond the geographical informations: the privileged connections are the results of the design of the transportation network

How are these fast connections distributed in the city ?
at which extent are they linked to home-work commuting ?

Analysis of the fast connections

Intuition : stations with similar connectivity patterns can exhibit some similarities

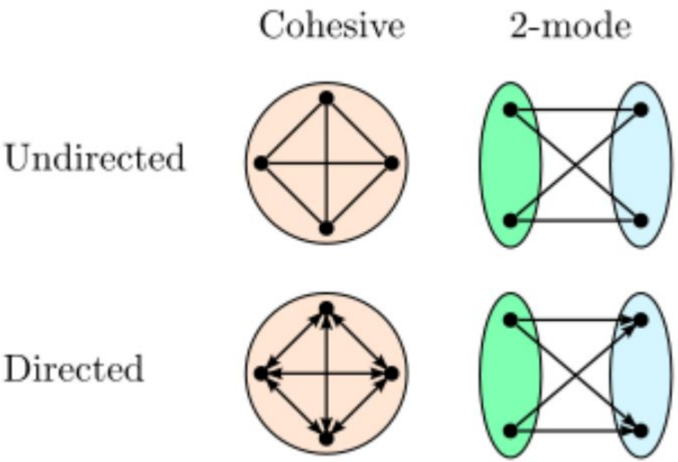
For instance :

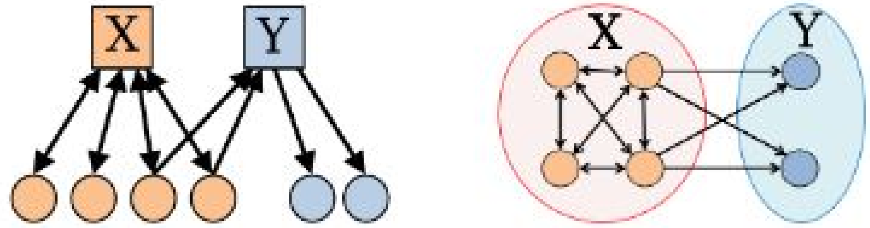
1) we expect that some stops located in a residential neighborhood have similar connections with respect to the rest of the network, as some might be linked to stops located in the city center and in working areas

2) nearby stops having the same connectivity patterns can yield some resilience to the system

Detection of underlying patterns

Building of an adjacency matrix of the fast connections





(a) Node community affiliations (b) Network G

Detection of underlying patterns

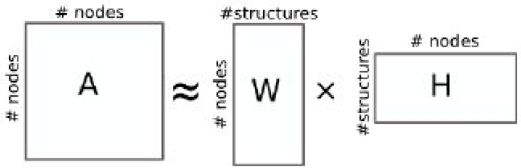
Non negative matrix factorization (NMF)

Given a non-negative matrix $\mathbf{A} \in \mathbb{R}_+^{m \times n}$, a non-negative matrix factorization in K components is:

$$\mathbf{A} \approx \mathbf{W}\ \mathbf{H} \tag{1}$$

$$a_{ij} = \sum_{k=1}^{K} w_{ik} h_{kj} \tag{2}$$

where $\mathbf{W} \in \mathbb{R}_+^{m \times K}$ and $\mathbf{H} \in \mathbb{R}_+^{K \times n}$



$$\hat{W}, \hat{H} = \underset{W,H \geq 0}{argmin} D(A, WH)$$

Transportation network analysis

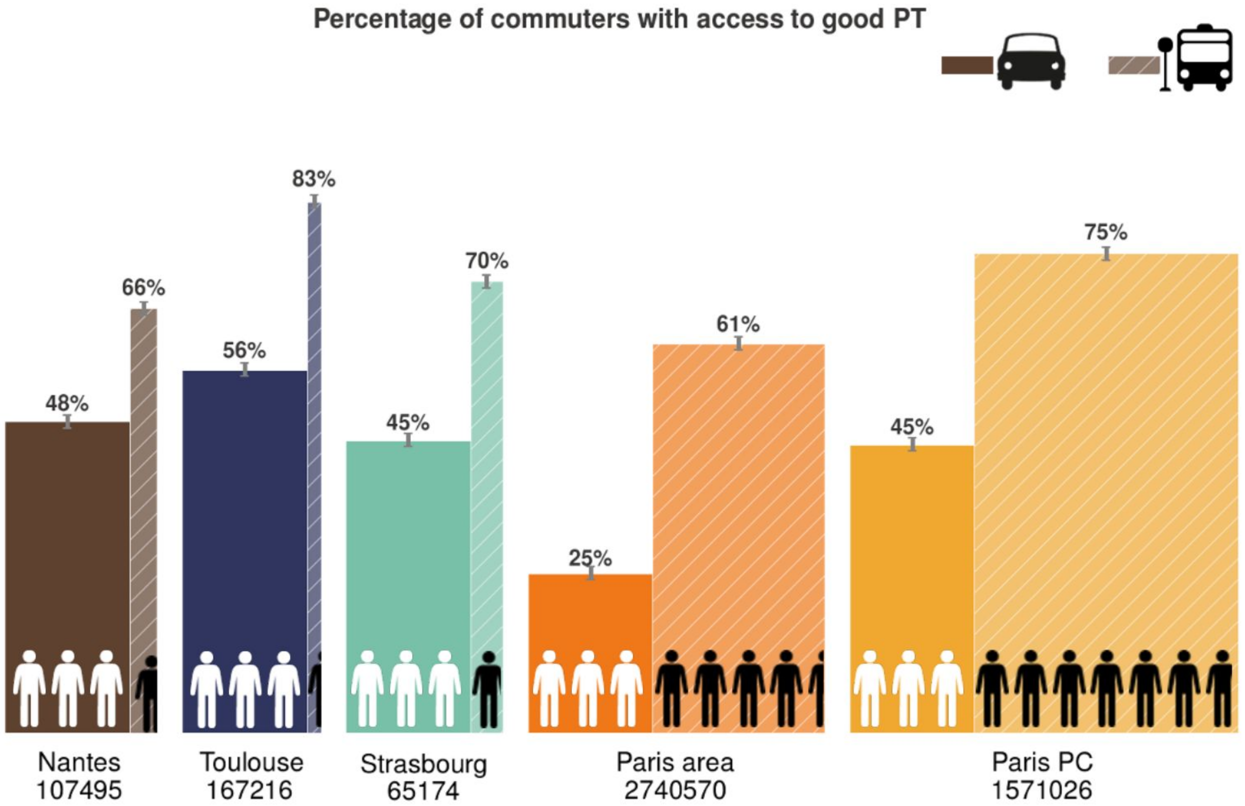
We run the method for different cities :

- 1) P-space multiedge representation of the transportation network

- 2) calculation of the shortest paths

- 3) extraction of patterns for different intervals of distances relevant for the city scale

Efficiency characterization



Summary

- Representation taking into account:
  - spatial embeddedness
  - multimodality
  - time information
- Adapted Dijkstra's algorithm
- Fingerprints of public transportation networks

Future work

- Integrating: bike sharing and car sharing

Thank you!

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http://rsos.royalsocietypublishing.org/content/3/7/160156

https://github.com/lalessan/user_basedPT

Shortest paths