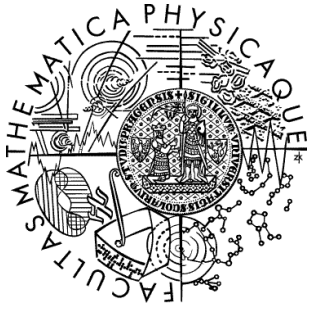


Remarks on Complex Navigation Systems

Vladislav Martínek and Michal Žemlička
Charles University, Faculty of Mathematics and Physics
martinek,zemlicka@ksi.mff.cuni.cz

Motivation

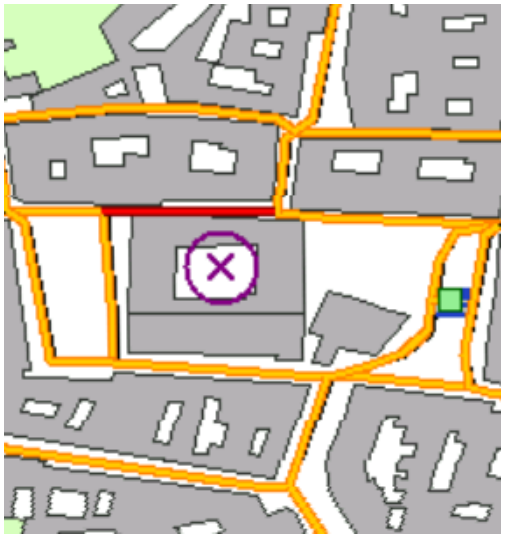
- ***How to get from one place to another as well as can be?***
- various types of **users/routes/transportation**
- Simple application:
  - can find a path using only one type of service
  - is not able to combine services when searching the best connection

JRGPS project

- Complex navigation in town/city
  - Combines **public transport services** and **walk**
- Off-line application
  - No dependency on actual connection availability
  - Lower cost for everyday use
  - Actualization on demand
- Mobile devices
  - Limited computation capacity

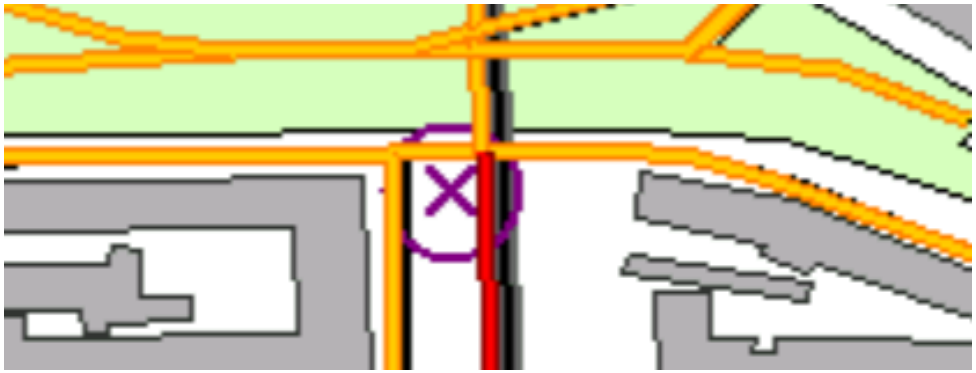
Issues of Pedestrian Navigation

- Pedestrian network
  - The path can typically start anytime
  - Time limited passages
  - **Starting position (GPS) must be within pedestrian network**
  - Public transportation refuges
  - …



Issues of Pedestrian Navigation

- Pedestrian network
  - The path can typically start anytime
  - Time limited passages
  - Starting position must be within pedestrian network
  - Public transportation refuges
  - **Grade-separated crossings**

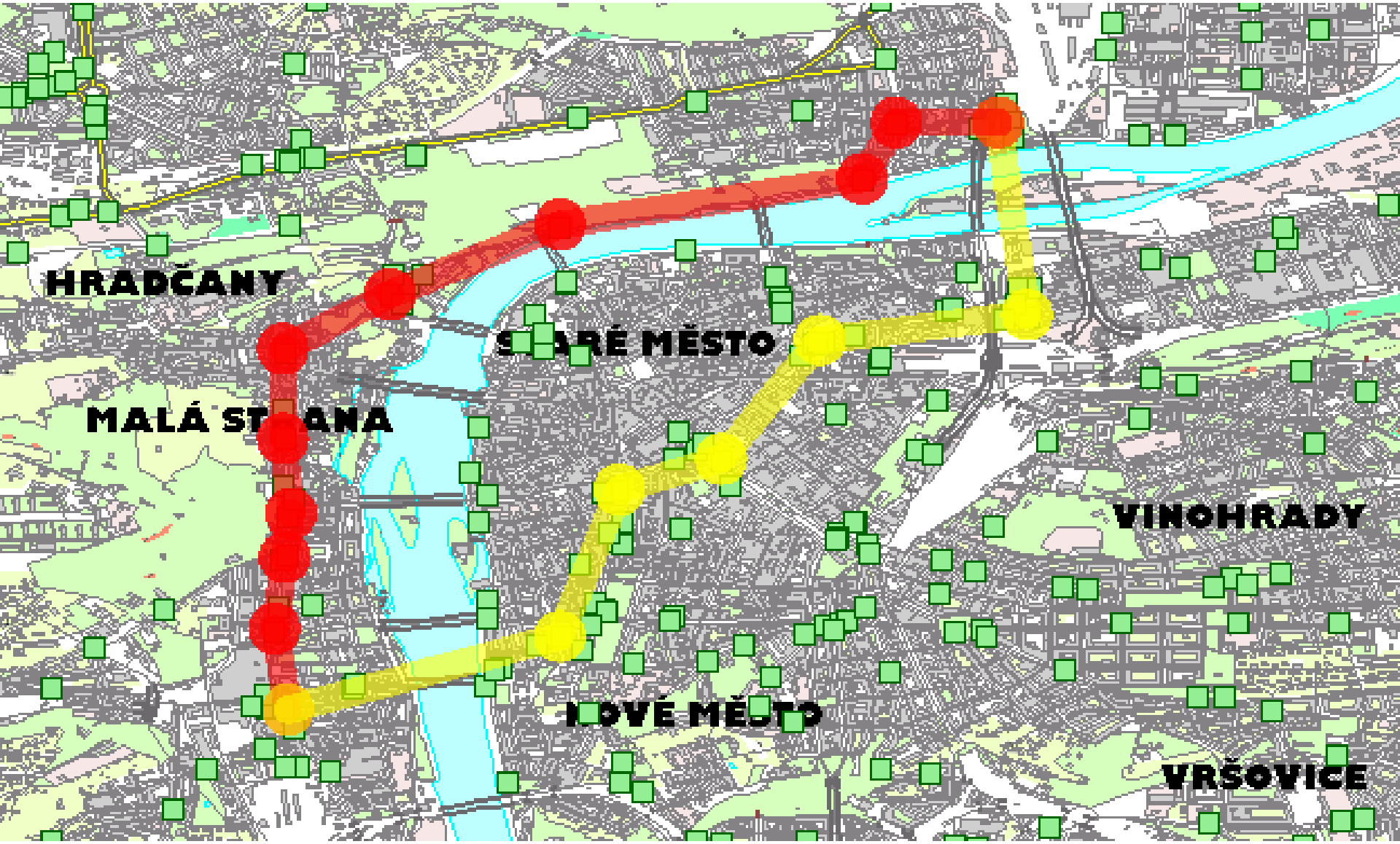


Issues of Pedestrian Navigation

- Pedestrian network
  - The path can typically start anytime
  - Time limited passages
  - Starting position must be within pedestrian network
  - Public transportation refuges
  - Grade-separated crossings
  - Crosswalks
  - Superelevation, barriers, accessibility of the path

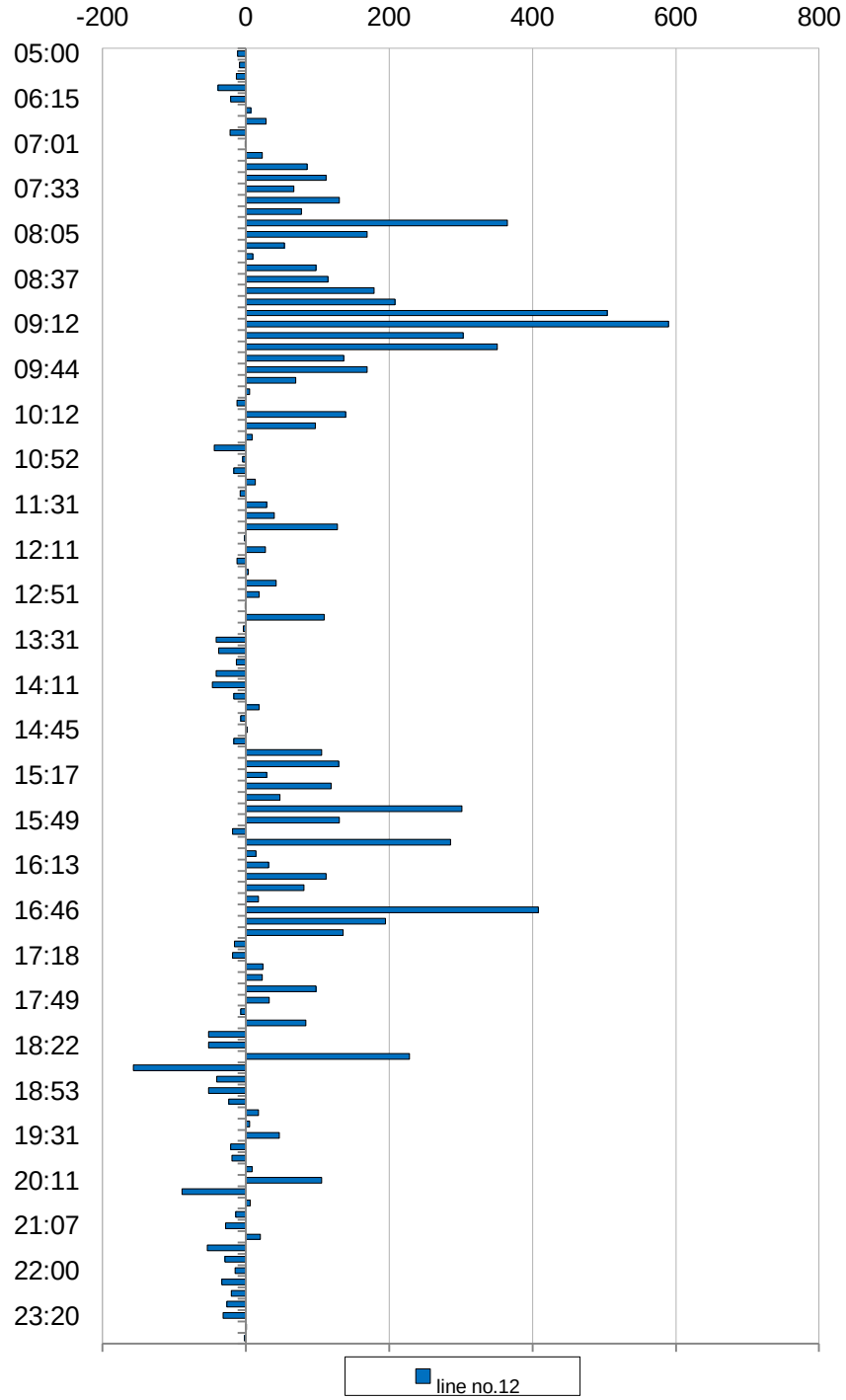
Issues of Navigation for Public Transportation

- Public transportation network
  - The path typically starts at certain moments or periodical intervals given by a timetables
  - **Path plan may be significantly different for two relatively close moments**
  - …


HRADČANY
MALÁ STRANA
VINOHRADY
VRŠOVICE

Issues of Navigation for Public Transportation

- Public transportation network
  - The path typically starts at certain moments or periodical intervals given by a timetables
  - Path plan may be significantly different for two relatively close moments
  - **Path reliability, frequency of services**
  - …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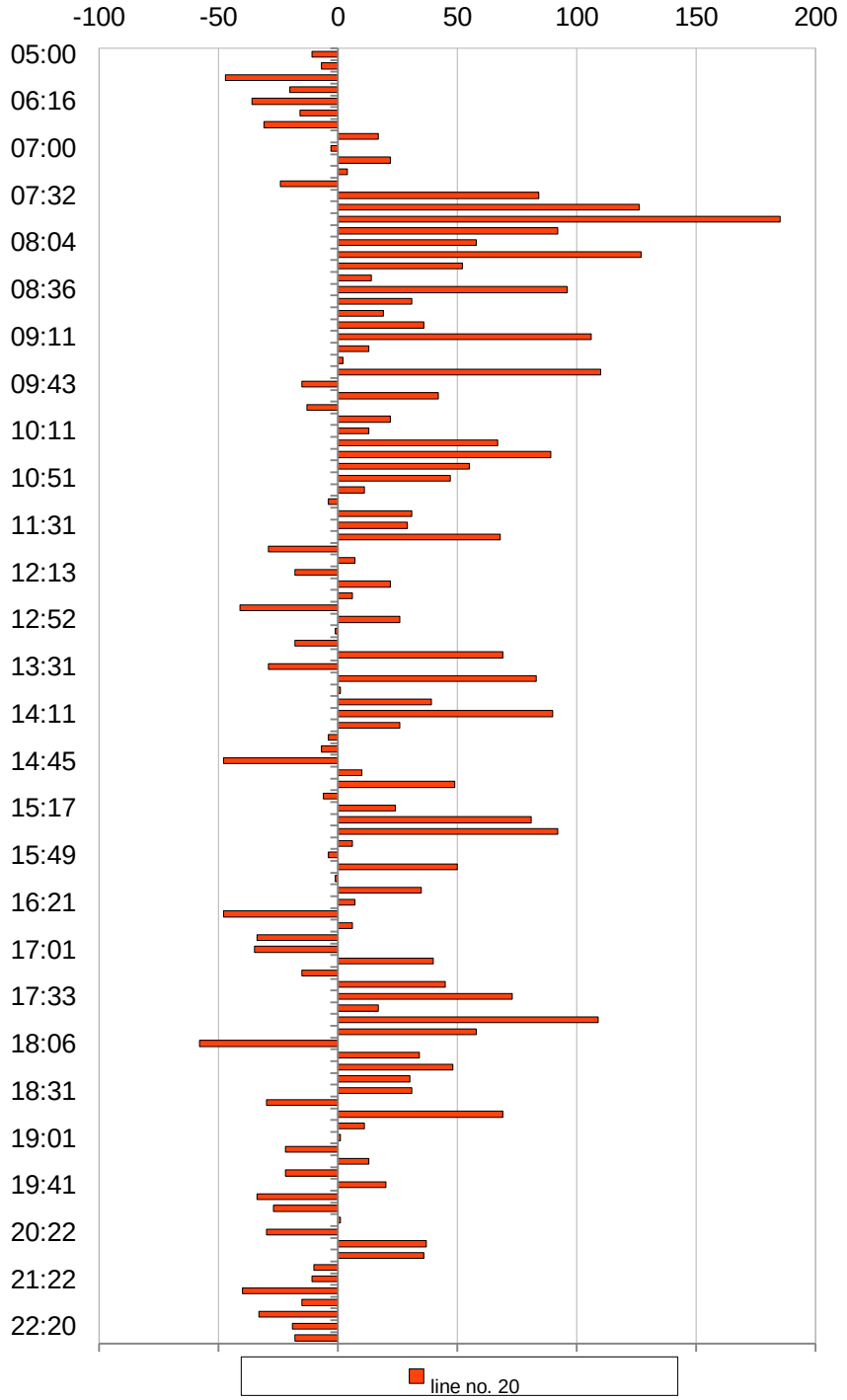
line no.12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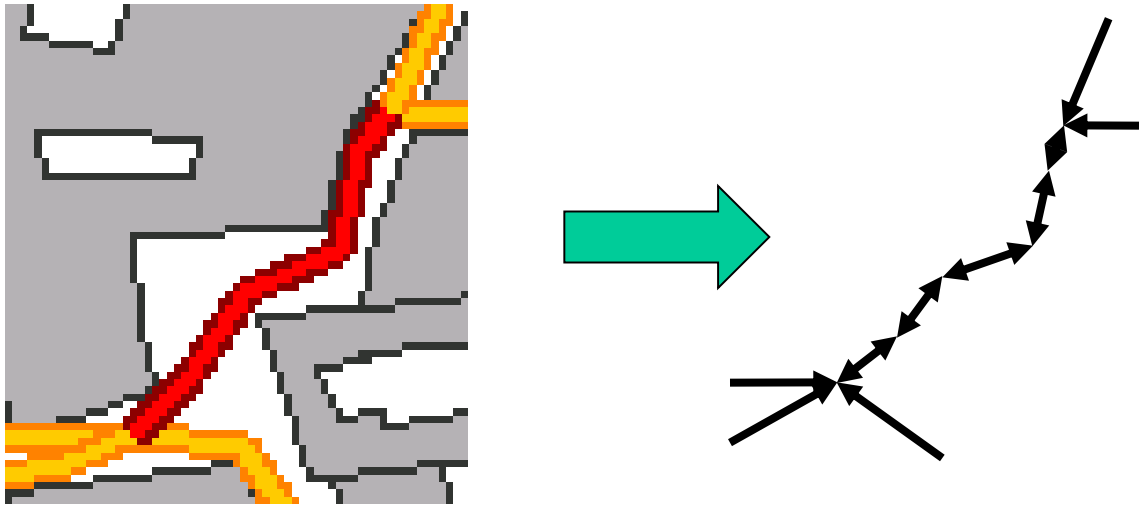
14:11
14:45
15:17
15:49
16:21
17:01
17:33
18:06
18:31
19:01
19:41
20:22
21:22
22:20
line no. 20

Issues of Navigation for Public Transportation

- Public transportation network
  - The path typically starts at certain moments or periodical intervals given by a timetables
  - Path plan may be significantly different for two relatively close moments
  - Path reliability, frequency of services
  - Time validity, exceptions
  - Length of platform, advantageous position within the vehicle

Some Solutions – Pedestrian Network Reduction

- The character of the path **is** important
  - Superelevation, barriers, accessibility of the path
- The shape of the street **is not** important



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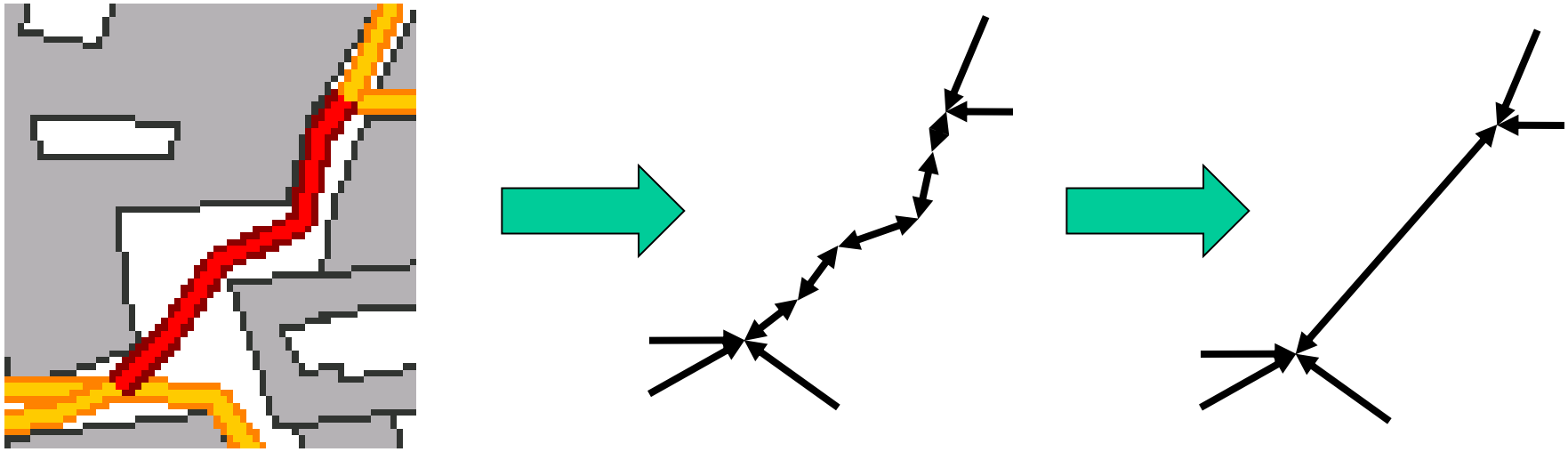
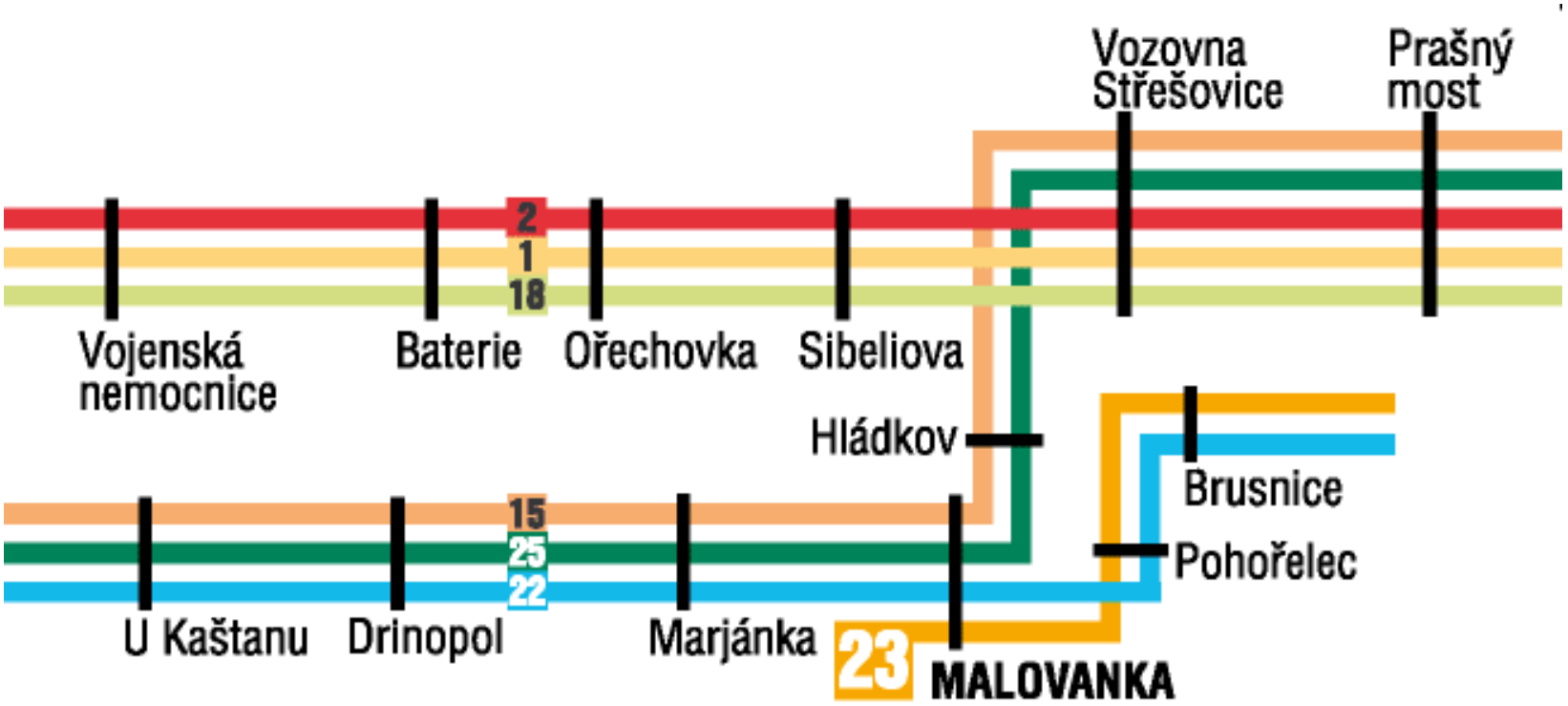
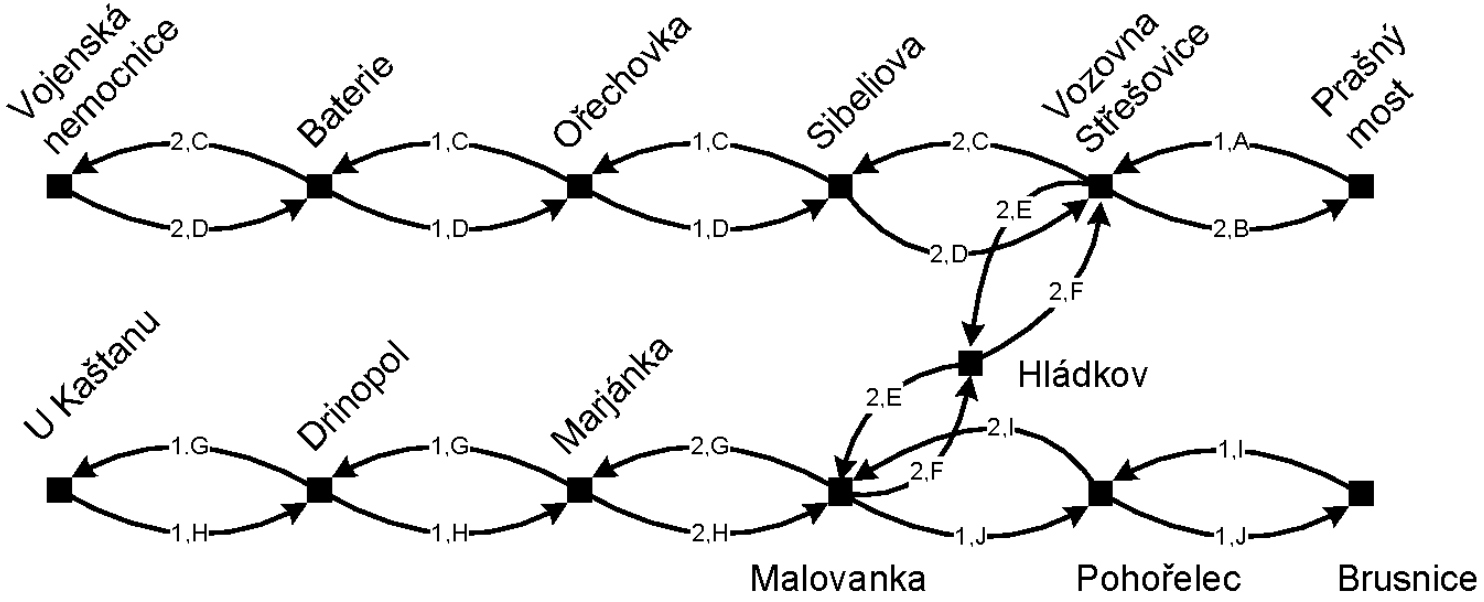


Some Solutions – PTN Reduction, original network



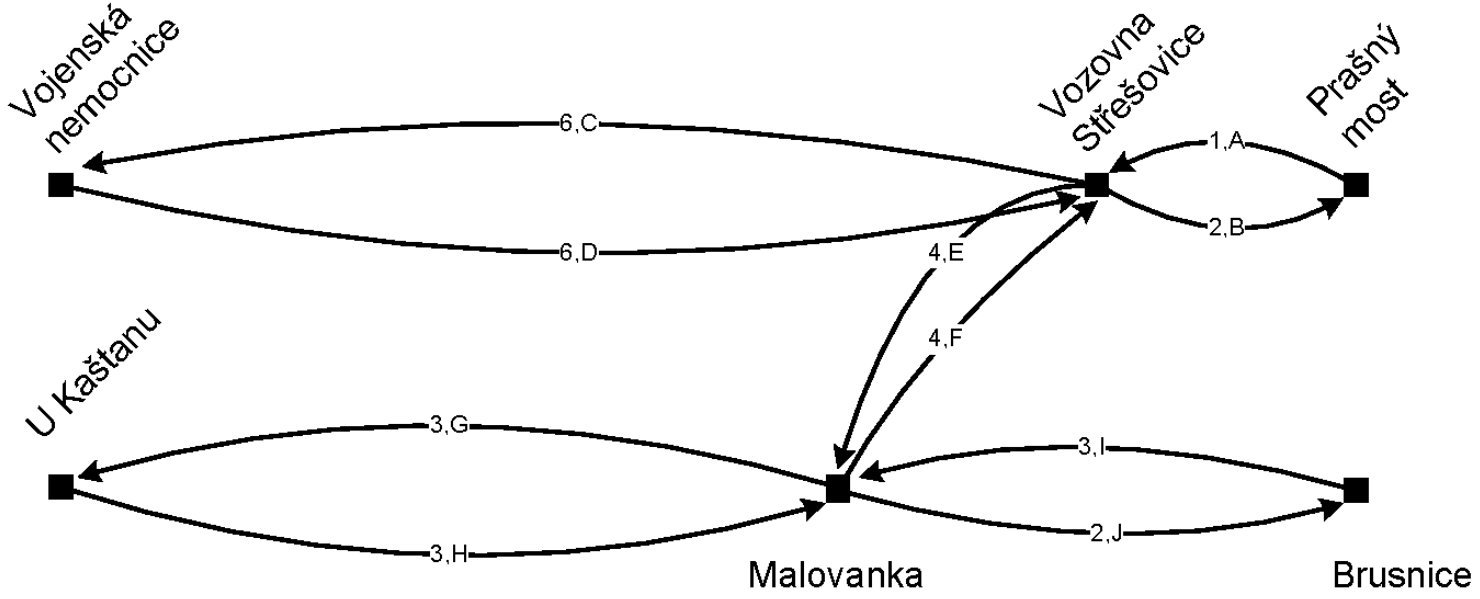
Some Solutions – PTN Reduction, level 1



Malovanka ... stop

2,A ... connection realized by „pseudoline A“ with travel time 2 minutes

Some Solutions – PTN Reduction, level 2

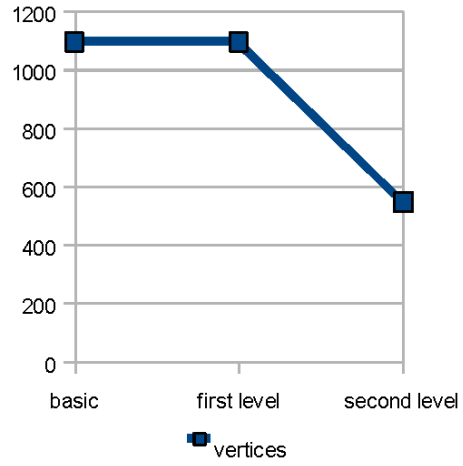


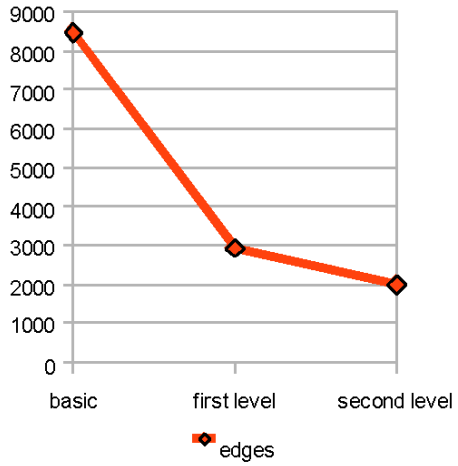
Malovanka ... stop

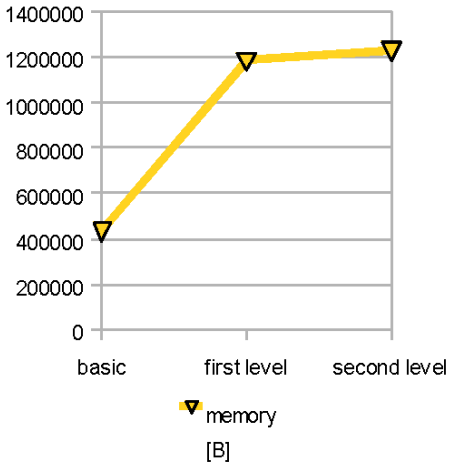
2,A ... connection realized by „pseudoline A“ with travel time 2 minutes

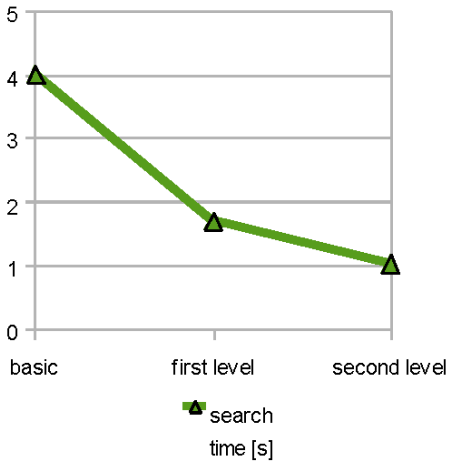
Some Solutions – PTN Reduction

- Orthogonal solution



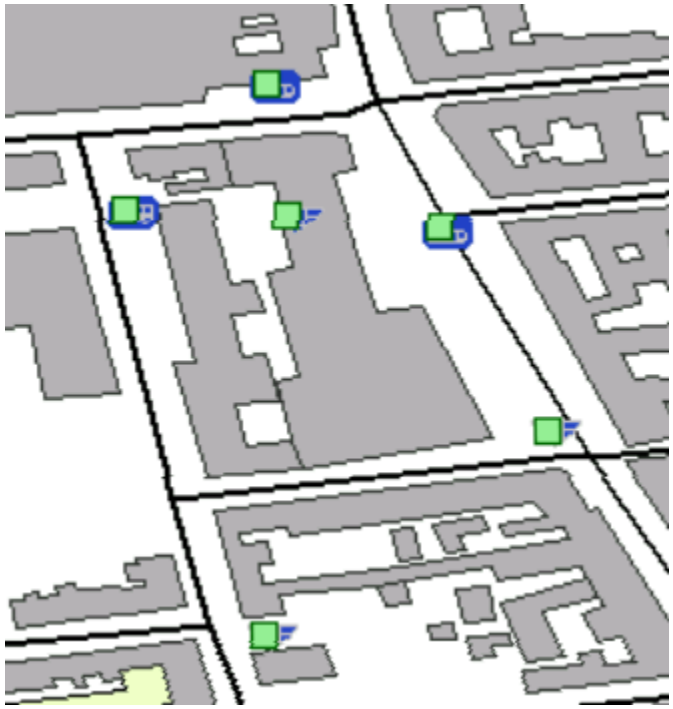






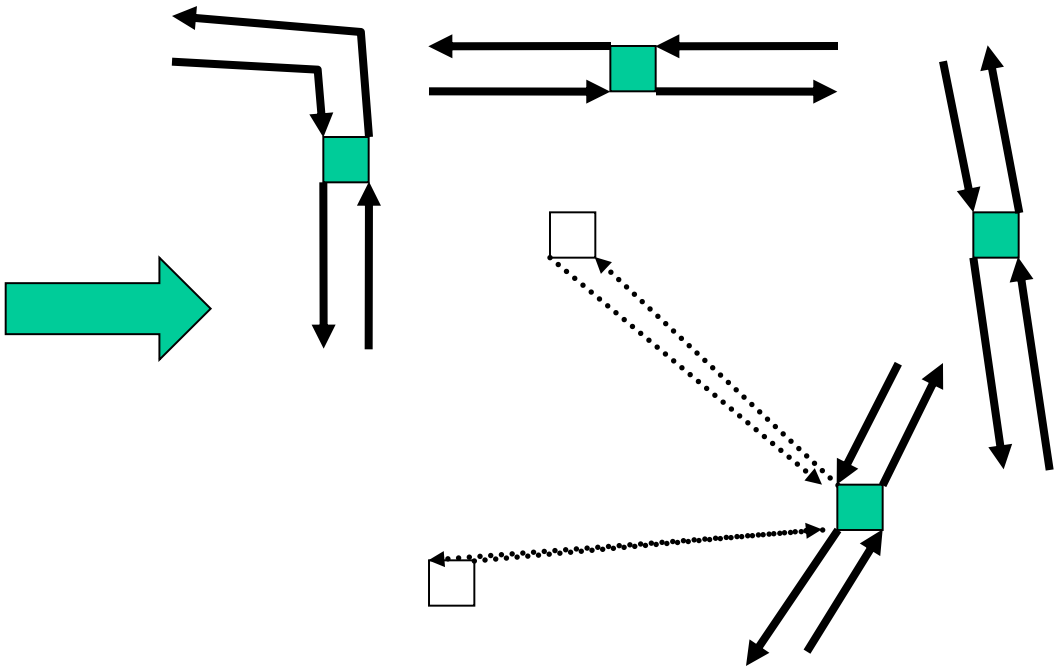
Some Solutions – Connecting PTN into Pedestrian network

- Street refuges



Some Solutions – Connecting PTN into Pedestrian network

- Street refuges
  - Mapping stops from timetables to street refuges

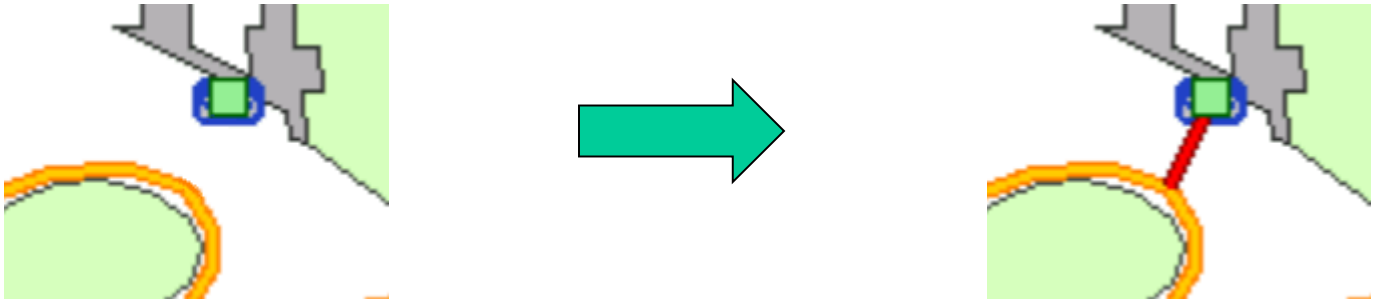


Some Solutions – Connecting PTN into Pedestrian network

- Street refuges
  - Mapping stops from timetables to street refuges
  - Positions of stop refuges in the map

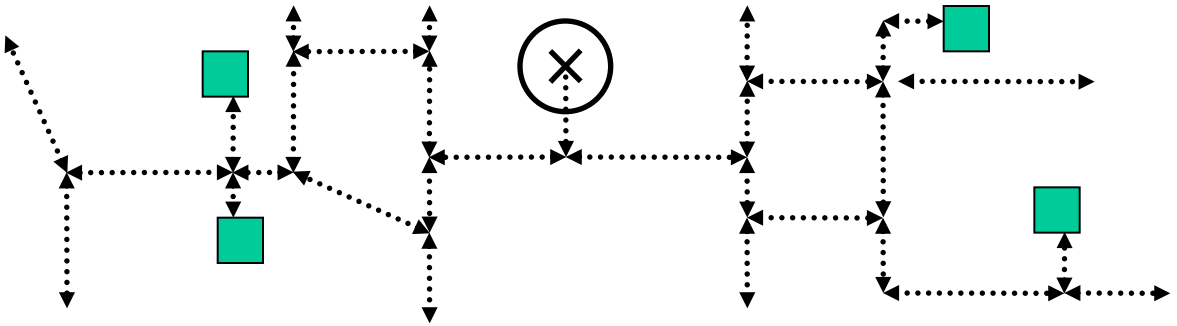
Some Solutions – Connecting PTN into Pedestrian network

- Street refuges
  - Mapping stops from timetables to street refuges
  - Positions of stop refuges in the map
  - Connection of refuges into the pedestrian network



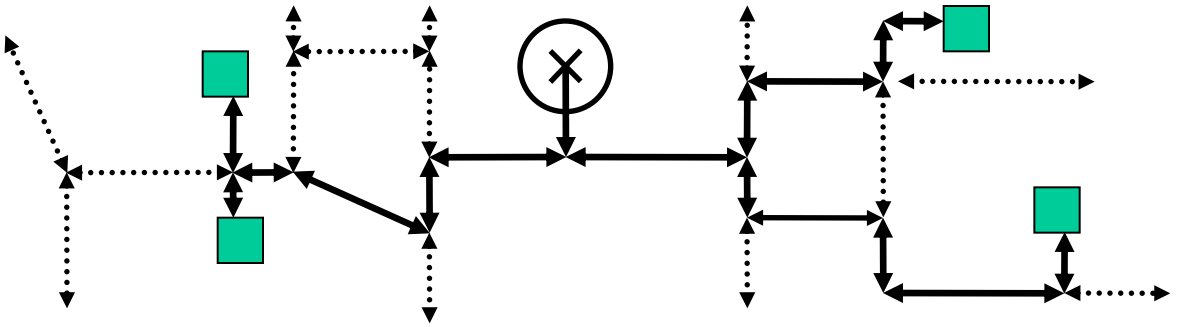
Some Solutions – Walk to PTN

- Searching walk paths from general position to the nearest stops of public transportation



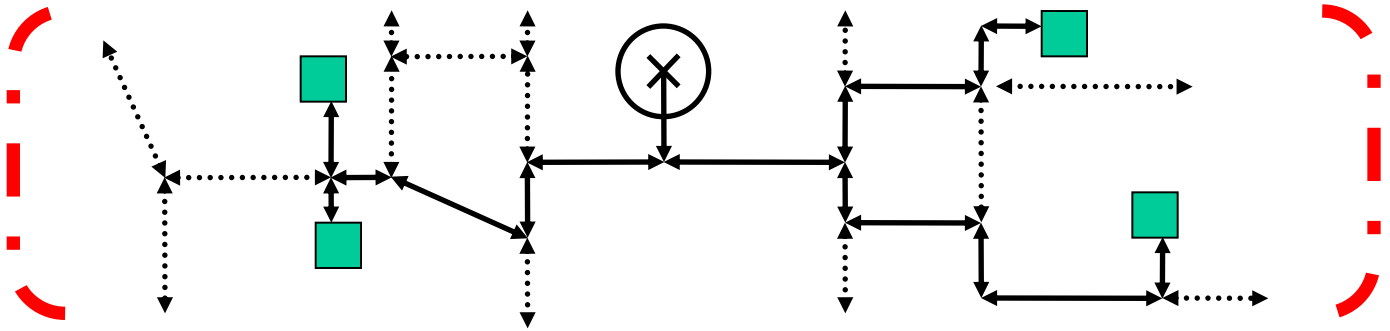
Some Solutions – Walk to PTN

- Searching walk paths from general position to the nearest stops of public transportation
  - Single iteration of BFS algorithm finds the paths to all nearby stops



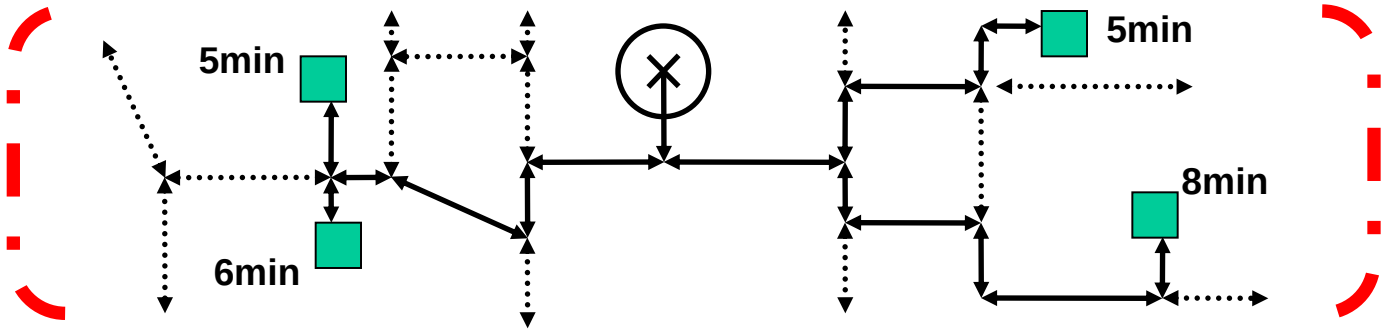
Some Solutions – Walk to PTN

- Searching walk paths from general position to the nearest stops of public transportation
  - Single iteration of BFS algorithm finds the paths to all nearby stops
  - The size of searched area is limited



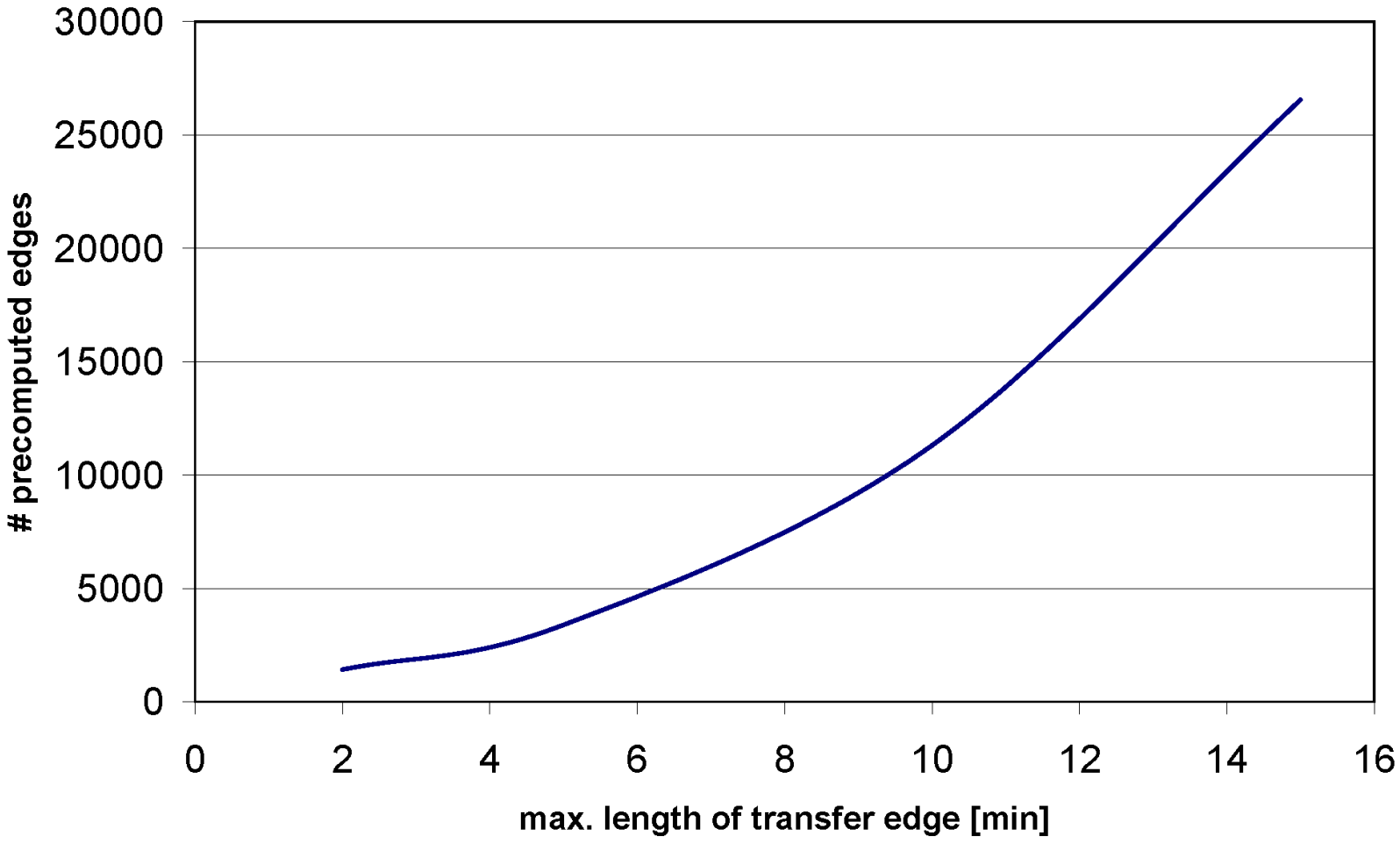
Some Solutions – Walk to PTN

- Searching walk paths from general position to the nearest stops of public transportation
  - Single iteration of BFS algorithm finds the paths to all nearby stops
  - The size of searched area is limited
  - The lengths of initial walk paths are propagated to the search of shortest connection in public transport



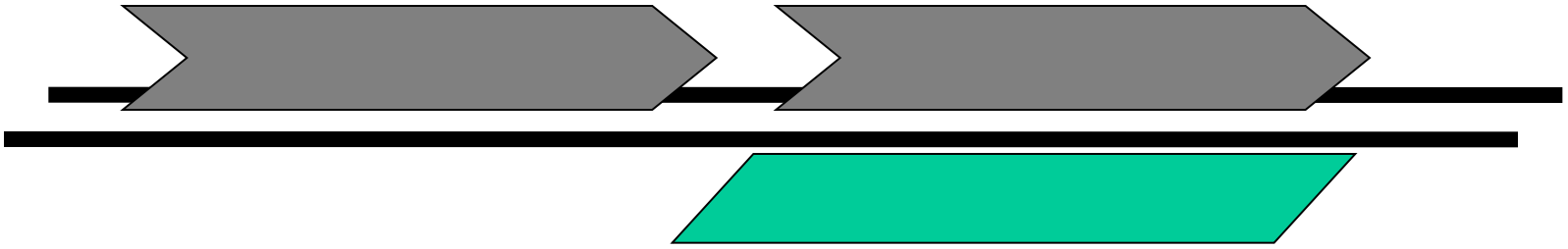
Some Solutions – Walk transfers inside PTN

- Searching walk transfer between stops of public transportation
  - Precomputed values saves computation time
  - The number of precomputed transfer edges grows strongly with the length of transfer
- The limit of length of precomputed transfer edges
  - High enough to make the connection search relevant
  - Low enough not to slow down the computation


30000
25000
20000
15000
10000
5000
0
precomputed edges
0
2
4
6
8
10
12
14
16
max. length of transfer edge [min]

Some Solutions – Unreliable transfers in PTN

- Unreliable transfers within the single refuge
  - Add a time for getting of the service

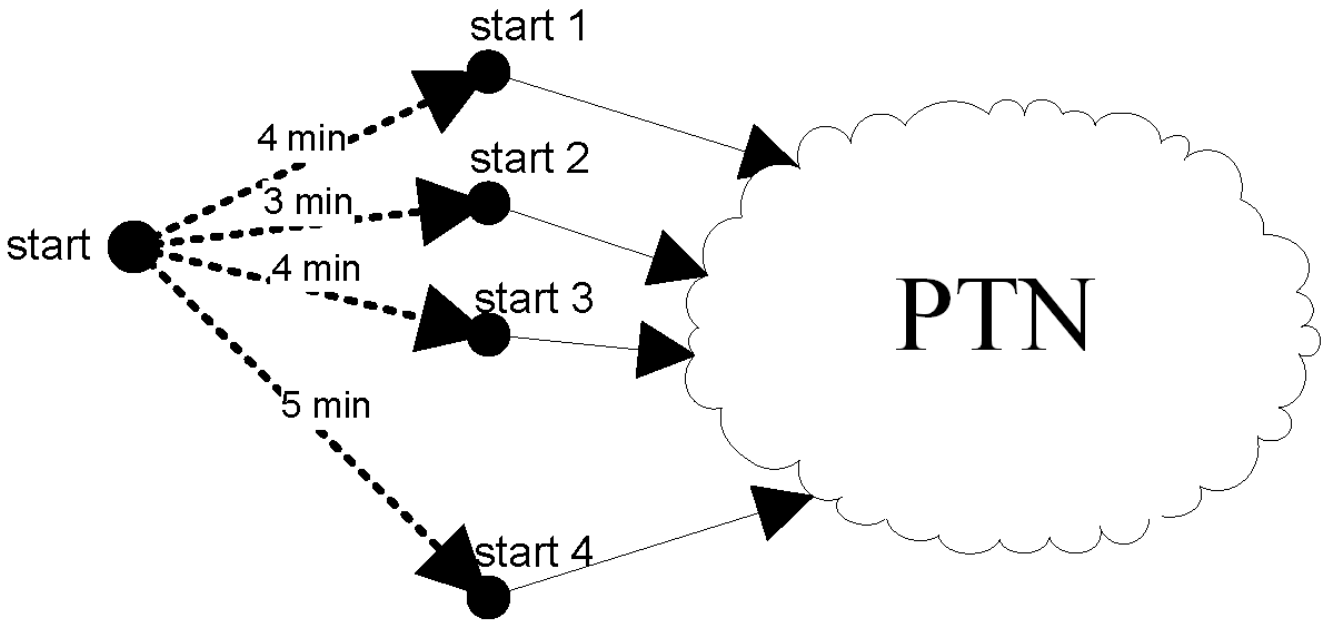


Some Solutions – Fail proof

- Reliability of path
  - Reliability of a service
  - Reliability of a section
  - Frequency of services during the path
- Failures of network
  - Excluding line
  - Excluding section

Some Solutions – User friendly

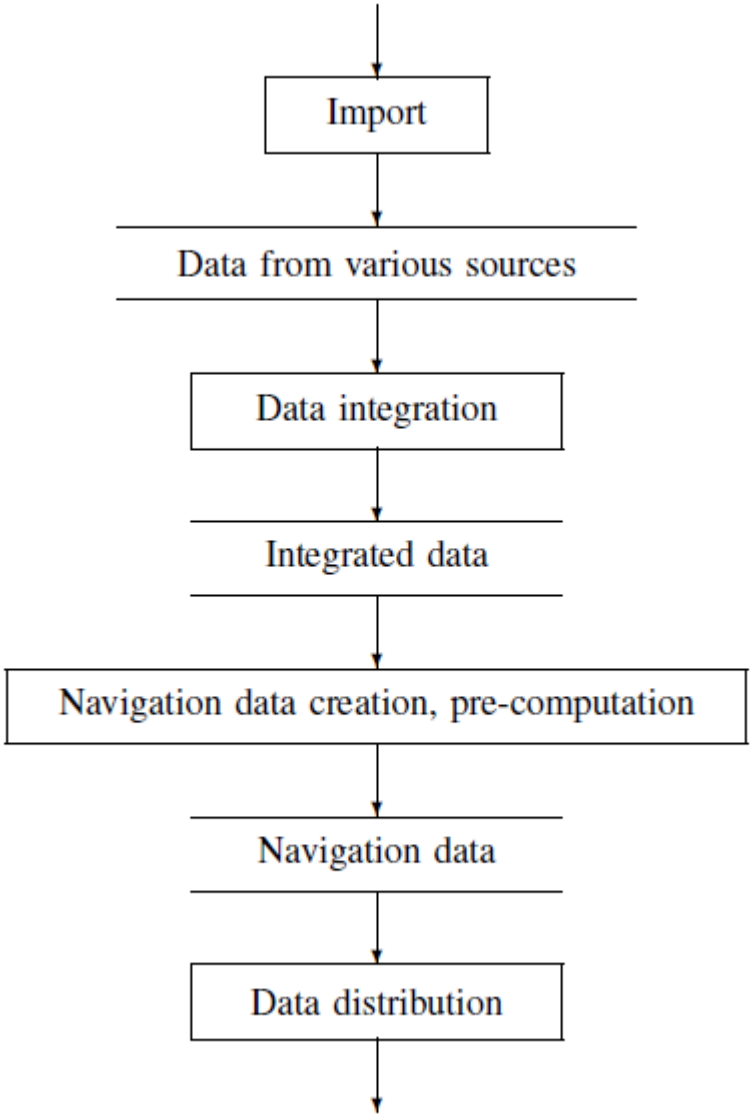
- User places
  - Predefined „home“, „office“, etc.

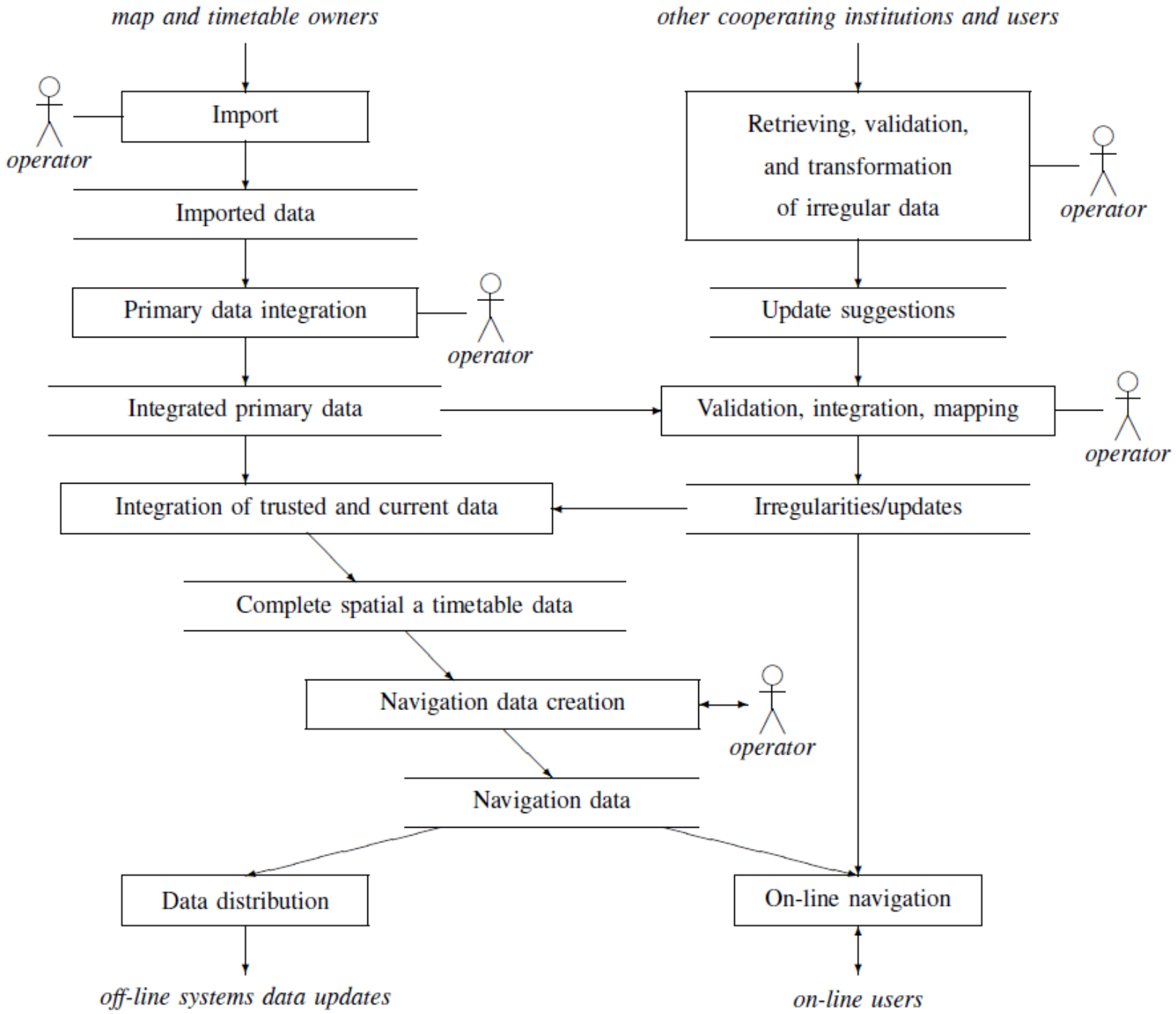


Some Solutions – User friendly

- User places
  - Predefined „home“, „office“, etc.
- User preferences
  - Walk speed
  - Barriers
  - Limit for continuous walk

System structure




map and timetable owners
other cooperating institutions and users
operator
Import
Retrieving, validation,
and transformation
of irregular data
operator
Imported data
Primary data integration
operator
Update suggestions
Integrated primary data
Validation, integration, mapping
operator
Integration of trusted and current data
Irregularities/updates
Complete spatial a timetable data
Navigation data creation
operator
Navigation data
Data distribution
On-line navigation
off-line systems data updates
on-line users

Advantages / Disadvantages

+ Path efficiency
  + Walk parts are not estimated in combined path
+ Environmental aspect

− Different planning in the search networks
− Different sources of data

Future Plans

- Multi-criteria path search
  - time, cost, reliability, safety, accessability …
  - points of interest
- More types of transportation
  - Hierarchy of transportation networks

Conclusion

- Complex navigation systems have a strong potential
  - Multi-criteria path search
- Both on-line and off-line services have advantages
  - Our off-line solution proves, that the computation capacity of today‘s mobile devices is sufficient
- Proper navigation of pedestrians requires very detailed map base

Combining networks – Complex Navigation

- Time dependent path sections
  - Does not tolerate late coming passengers
- Time independent path sections
  - Can be moved in time to satisfy various conditions

JRGPS project

- http://www.ksi.mff.cuni.cz/~zemlicka/projects/team/JRGPS/

V. Martínek and M. Žemlička, „Speeding up shortest path search in public transport networks,“ in *DATESO 2009*, K. Richta, J. Pokorný, and V. Snášel, Eds. Prague, Czech Republic: Czech Technical University in Prague, 2009, pp. 1-12.

V. Martínek and M. Žemlička, „Some issues and soutions for complex navigation systems: Experience from JRGPS project,“ in *2009 Fifth International Conference on Systems*. IEEE CS Press, 2010, pp. 92-98.