# Exploratory analysis of pedestrian flow characteristics in mobility hubs using trajectory data

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# Outline

- Motivation and related work
- Data collection
- Exploratory analysis – microscopic and macroscopic characteristics
  - Qualitative
  - Quantitative
- Conclusion and future work

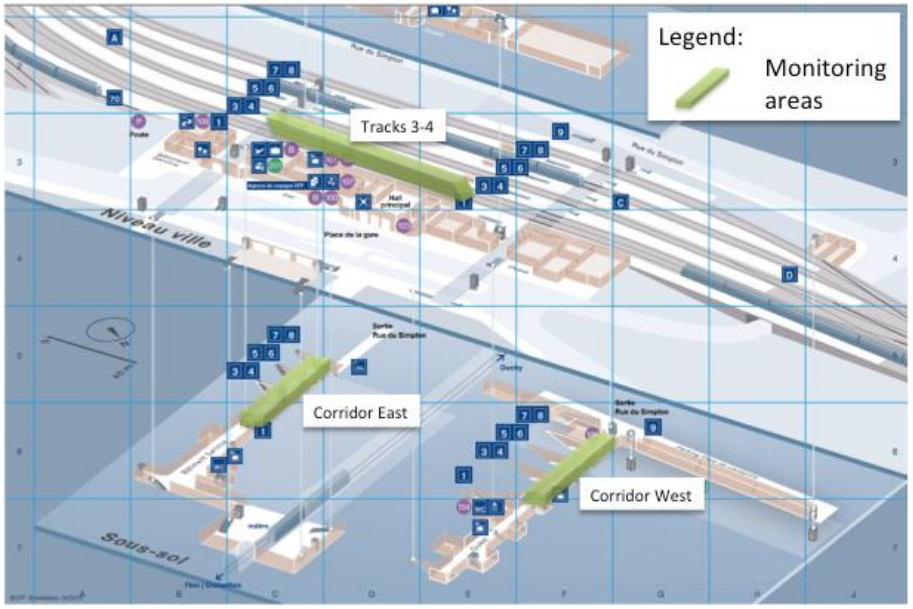
# Motivation and related work 1/2

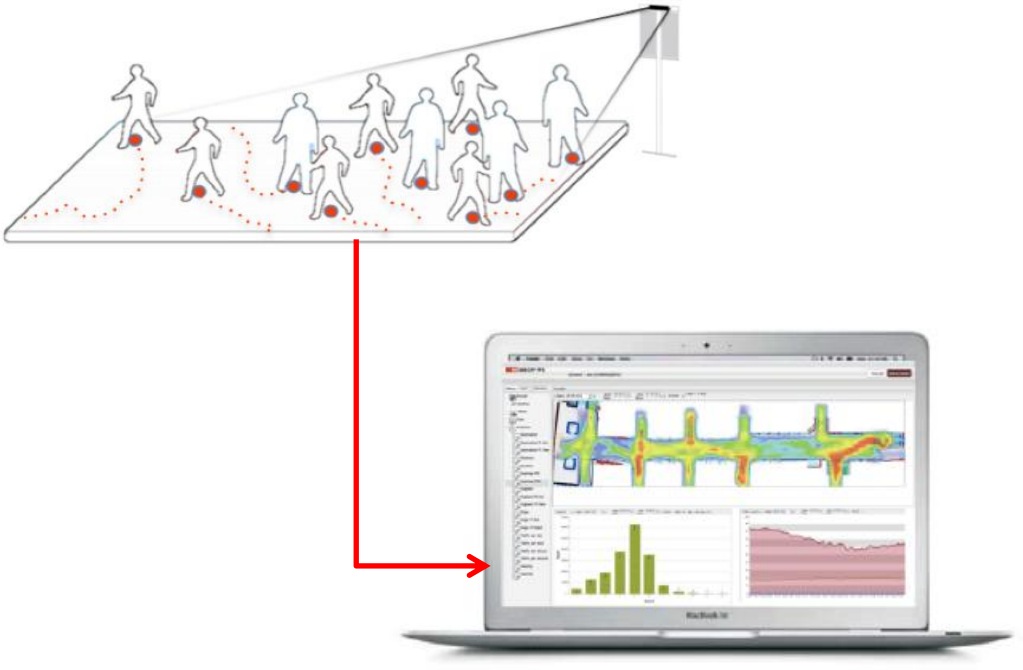
- Observable trend - increasing number of people settling in cities
  - Significant stress on the public transportation infrastructure
- Predictions - by the year of 2030 the number of passengers commuting between Lausanne and Geneva will have increased from 50,000 to 100,000
- How to provide efficient management of the predicted increase in number of pedestrians at train stations
  - Simple application of a particular policy → costly trial and error solutions
  - Investigation of the best approach
- Pedestrian models capable of representing the real phenomena are necessary

# Motivation and related work 2/2

- Pedestrian movement behaviour is still not well understood
- Fundamental diagram
  - Maximal value of flow: 1.2 $(ms)^{-1}$ - 1.8$(ms)^{-1}$
  - Jam-density: 3.8 ped/$m^2$ - 10 ped/$m^2$
  - Maximum flow density: 1.7ped/$m^2$ - 7 ped/$m^2$
- Development of the better data analysis methods based on precise data is significant
- Aim:
  - Improve research on the pedestrian flow theory
  - Develop operational tools for policy makers

# Data collection



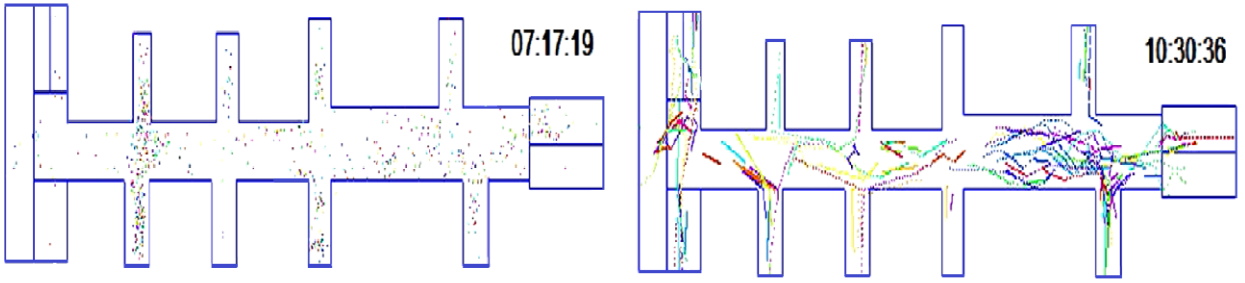



- 76 smart sensors capture flow at Lausanne train station
  - Corridors West (PIW) and East (PIE)
  - Tracks 3-4
- People are automatically:
  - Located in 3D
  - Tracked across time

# Exploratory data analysis

- Better understanding and explanation of the pedestrian walking behaviour in normal situations
- Time-space patterns
- Qualitative analysis
  - Macroscopic and microscopic aspects
- Quantitative analysis
  - Effects of congestion on pedestrian dynamics
  - Effects of different spatial aggregation levels on observables
- Visualization tool for pedestrian space-time motion

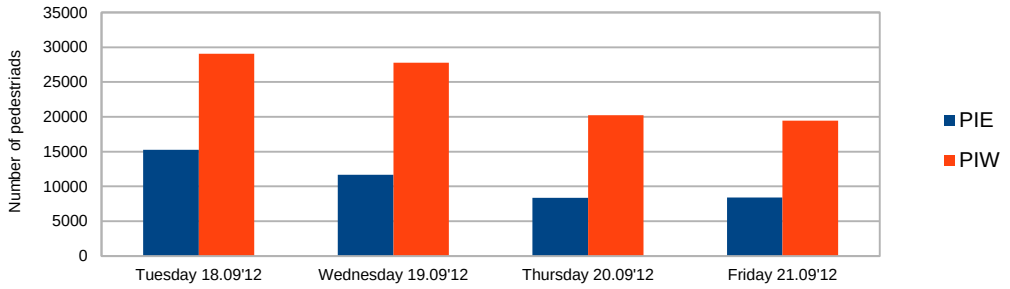
**PIW**



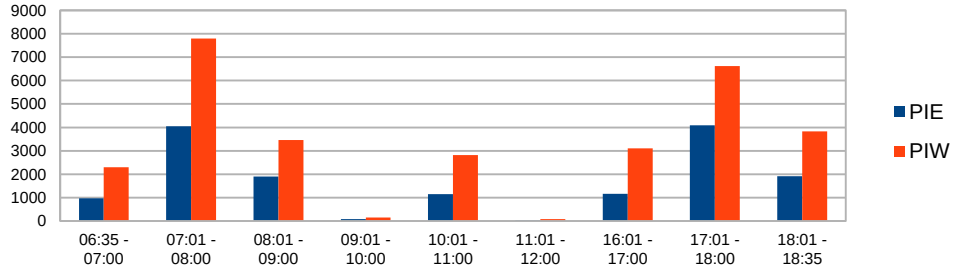
# Exploratory data analysis

Time – space patterns

# Critical time

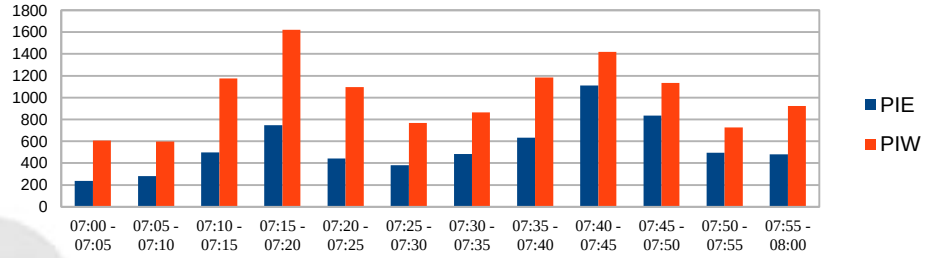



Decrease in traffic over the week days for PIE and PIW
Higher rate of traffic observed for PIW
The most critical (peak) day - Tuesday




Two critical periods of time:

- 7am - 8am
- 5pm - 6pm




The most critical time:

- From 7:10 am to 7:25 am
- From 7:35 am to 7:50 am

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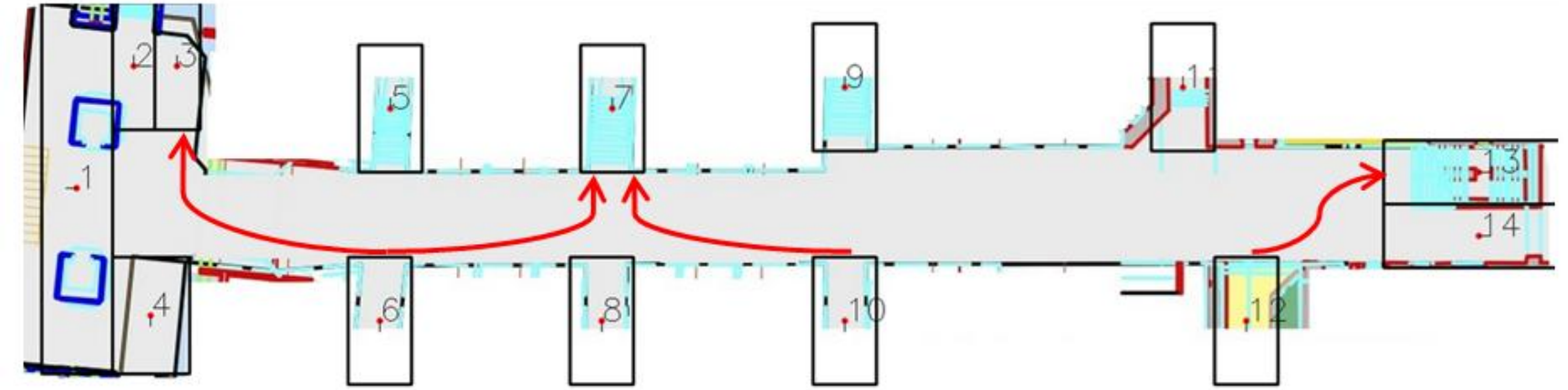
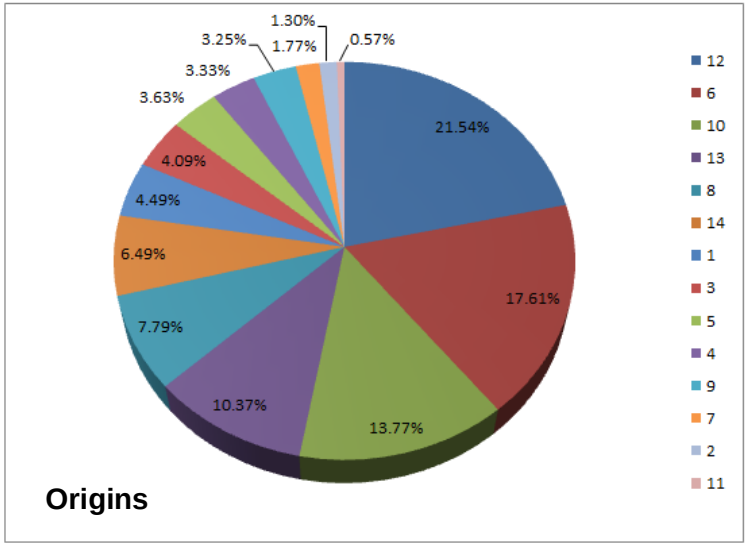
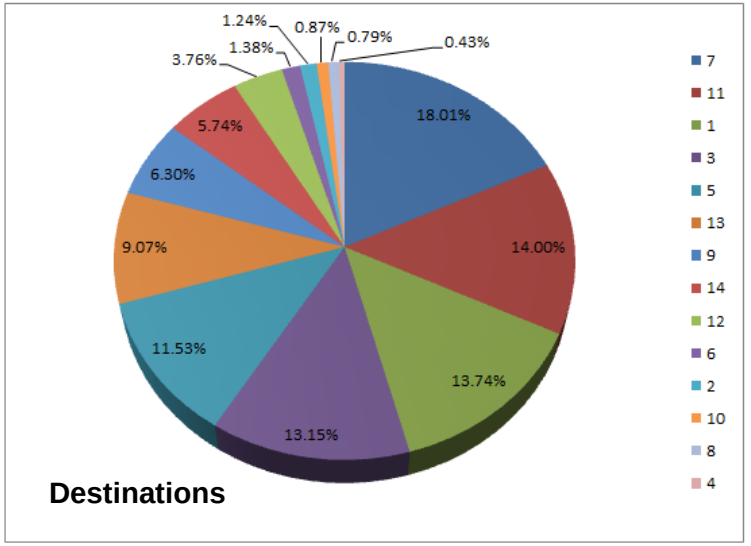
# Frequently used paths and areas

## PIW - peak day

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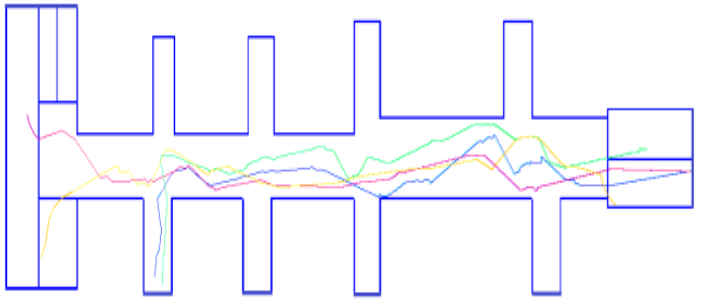
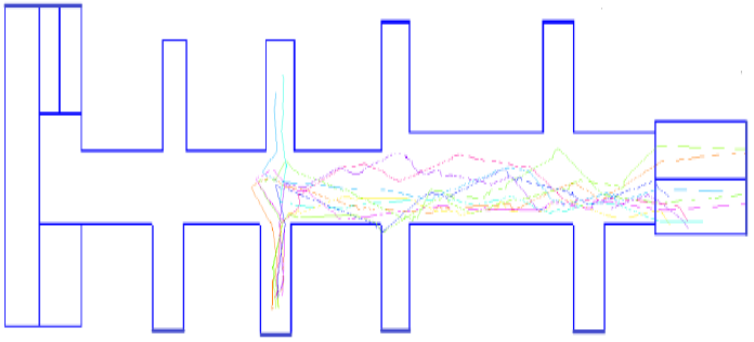
# Exploratory data analysis

Qualitative data analysis

# Microscopic data analysis
## PIW corridor



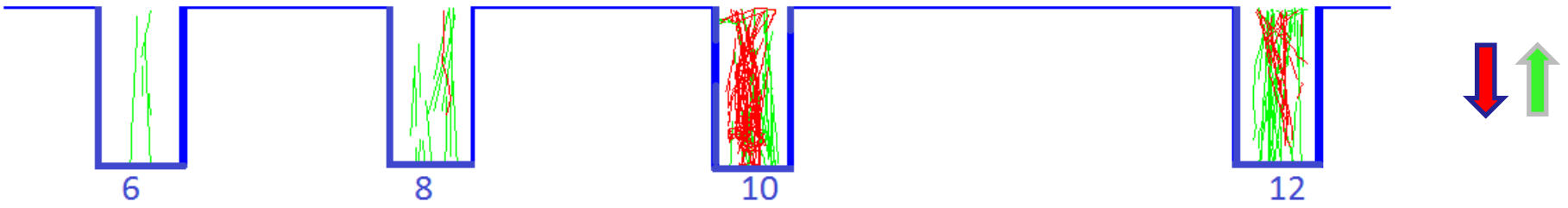
18.09.2012. 10:30-10:32



18.09.2012. 07:16-07:18

- No preference for the left or right hand side
- Pedestrians form groups of people walking in the same direction rather than lanes
- Lateral deviations
  - The ability to achieve movement in the form of a straight line decreases with the increase in distance to be passed
- Pedestrians use space more efficiently when the congestion level deteriorates
  - More available walking area is occupied

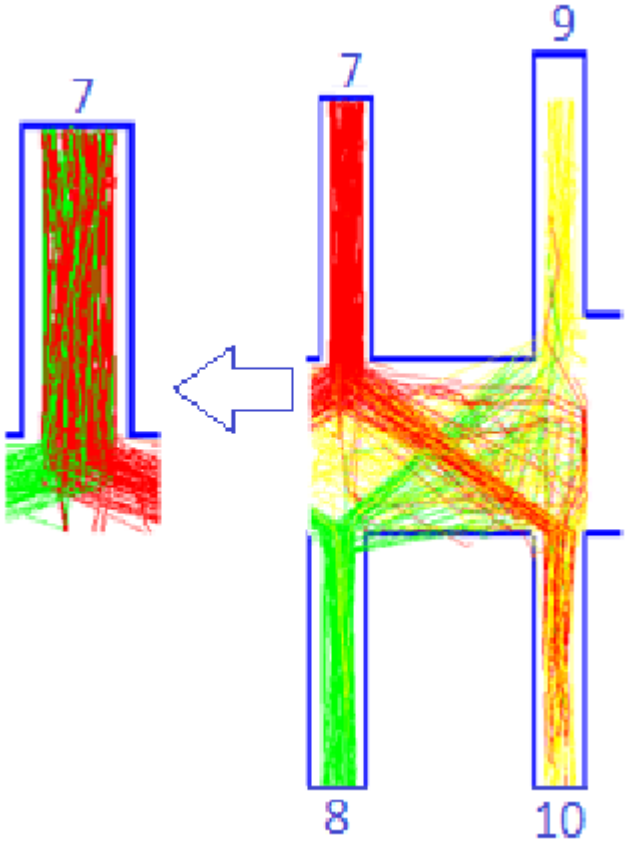
# Microscopic data analysis
## PIW ramps and stairs




- In shorter segments pedestrians are able to walk in a straighter line
- Unidirectional flow and a lower level of congestion
  - People tend to increase the distance between themselves and walls if possible
- Unidirectional flow and a higher level of congestion
  - The whole walkable area is used
- Bidirectional and mostly balanced flow
  - Whole available walking area is used
  - Slower pedestrians have a tendency to walk closer to the handrails
- Bidirectional and unbalanced
  - The dominant flow tends to use the middle part of an available walkable area
  - Pedestrians constituting the opposite flow form groups that use the rest of the available space

# Macroscopic data analysis

## Self organization

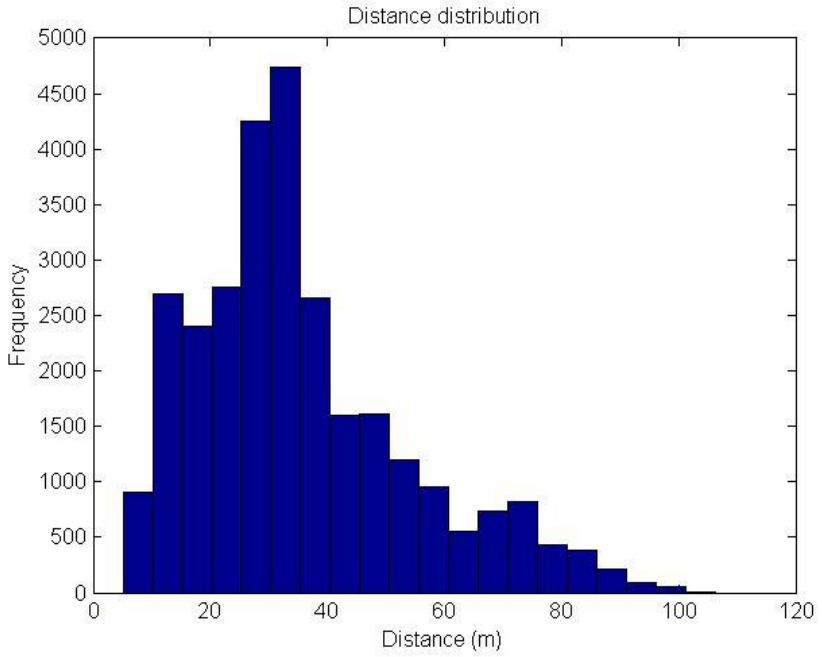


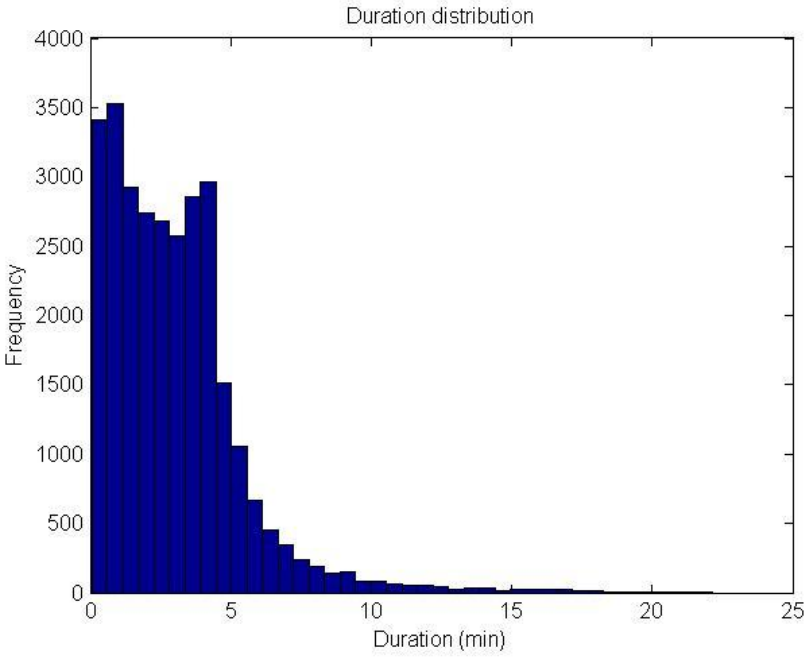

- Cross flow
  - Lane formation
  - Stripe formation
- Hypothesis: lane allows for a more comfortable flow for people who walk in the same direction
- Merging flow
  - Two streams aggregate forming one main stream
  - Whole available walking area is occupied

# Exploratory data analysis

Quantitative data analysis

# Distances and durations




PIW - peak day

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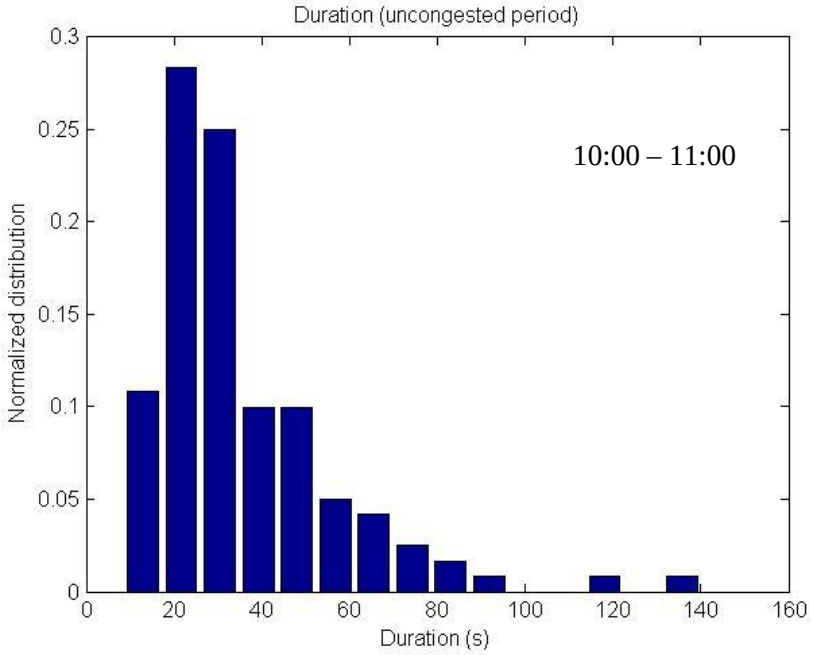
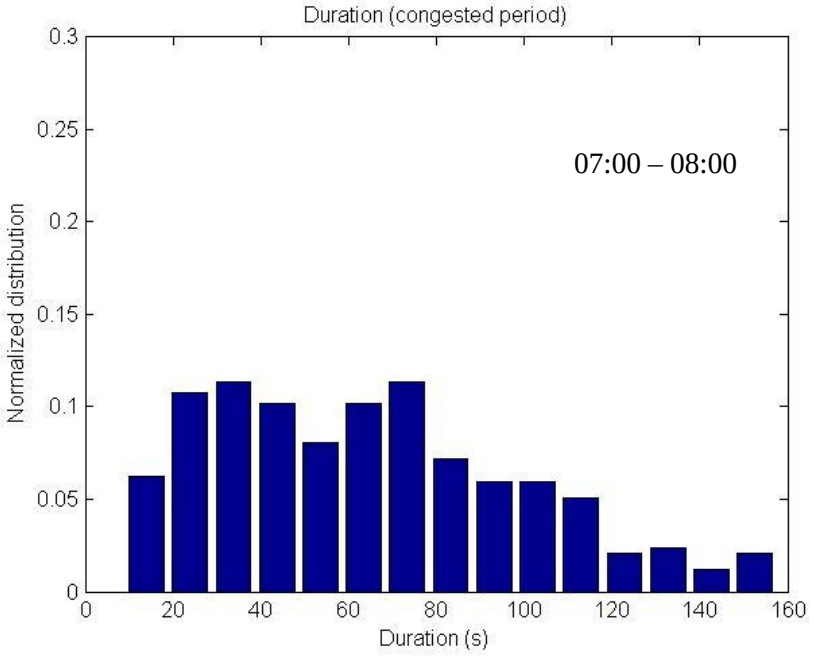
# Duration – impact of congestion

PIW: zone 12- zone 13




Decrease in the average time: 45%

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# Density – grid space representation

- The grid based method transforms the space into cell regions
  - Each cell is seen as entirely homogenous

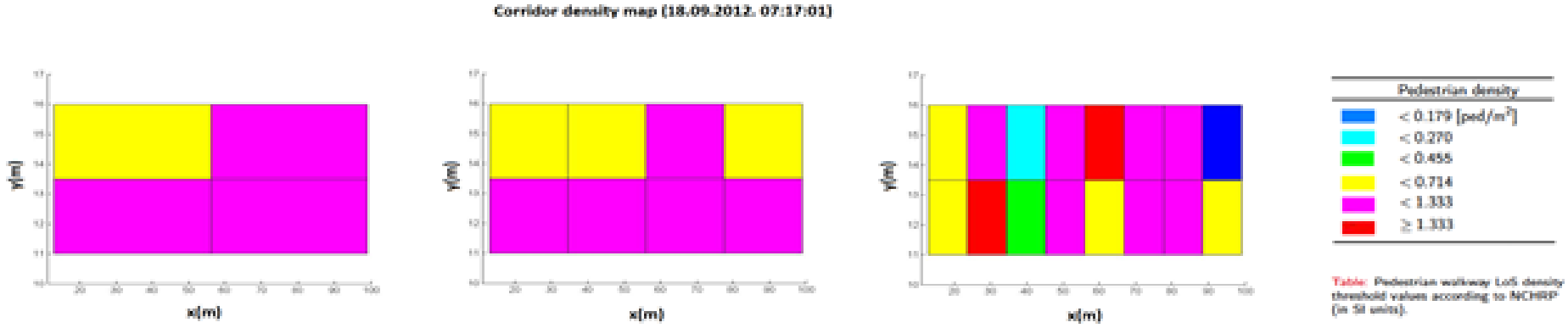
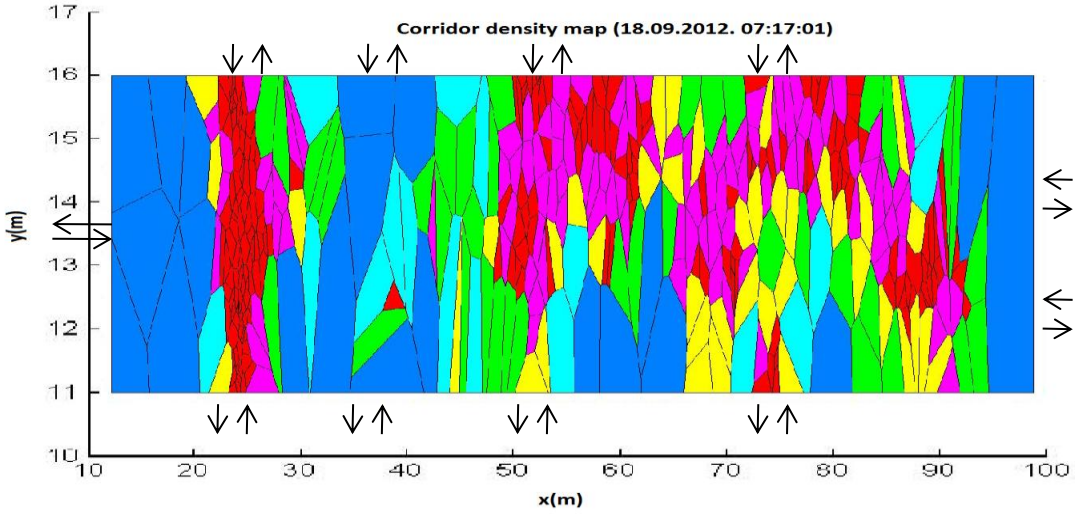



Table: Pedestrian walkway LoS density threshold values according to NCHRP (in SI units).

- Cell sizes: 2.5m ×43m, 2.5m ×21.5m, 2.5m×10.75m
- The aggregation leads to the concealment of essential information
- MAUP effect
  - Results are not independent of the scale and boundaries
  - Each size and boundary change affects the proportion of the number of pedestrians related to a specific space unit

# Density – Voronoi space representation

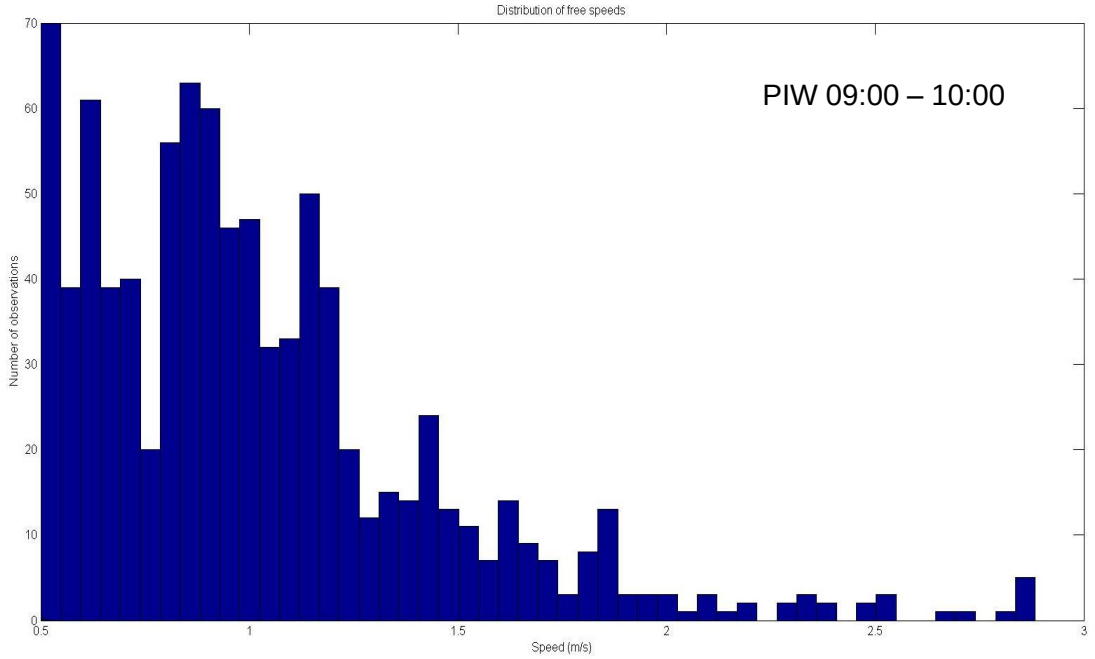



| Pedestrian density |
|---|
| $< 0.179$ [ped/m$^2$] |
| $< 0.270$ |
| $< 0.455$ |
| $< 0.714$ |
| $< 1.333$ |
| $\geq 1.333$ |

Table: Pedestrian walkway LoS density threshold values according to NCHRP (in SI units).

- MAUP effects can be alleviated by decomposition of the space at an individual pedestrian level
  - Voronoi structures - all space locations are associated with the closest pedestrian in respect of the Euclidean distance
- Issues:
  - Human percepion is not taken into account → additively weighted Voronoi diagram
  - Personal polygons overlap with the obstacles → visibility graph
  - Small polygons allocated to pedestrians in very dense areas → order-k Voronoi diagram
  - Large polygons allocated to pedestrians at the rims of the groups → limit the size of personal polygons

# Free flow speed distribution




- Free flow speed - speed pedestrians walk with when they are not constrained
  - Voronoi based personal region - density less than 0.05 ped/$m^2$
- Anomaly - a large percentage of the speed values close to zero
  - A significant number of people have been observed in a standing position
  - The degree of reliability of the collected data

# Conclusion and further work 1/2

- Assumption: the used data set of individual trajectories is insufficiently good representation of the reality
- Note: all results will be validated in the very near future on the new data set available for the two weeks in February 2013
- Qualitative analysis
  - Tendency to keep a certain distance from the walls whenever possible
  - Increase in distance to be passed → higher deviations from a straight line
  - No right or left hand side preference
  - Groups of people walking in the same direction
  - Lanes → better efficiency of movement when traffic conditions deteriorate

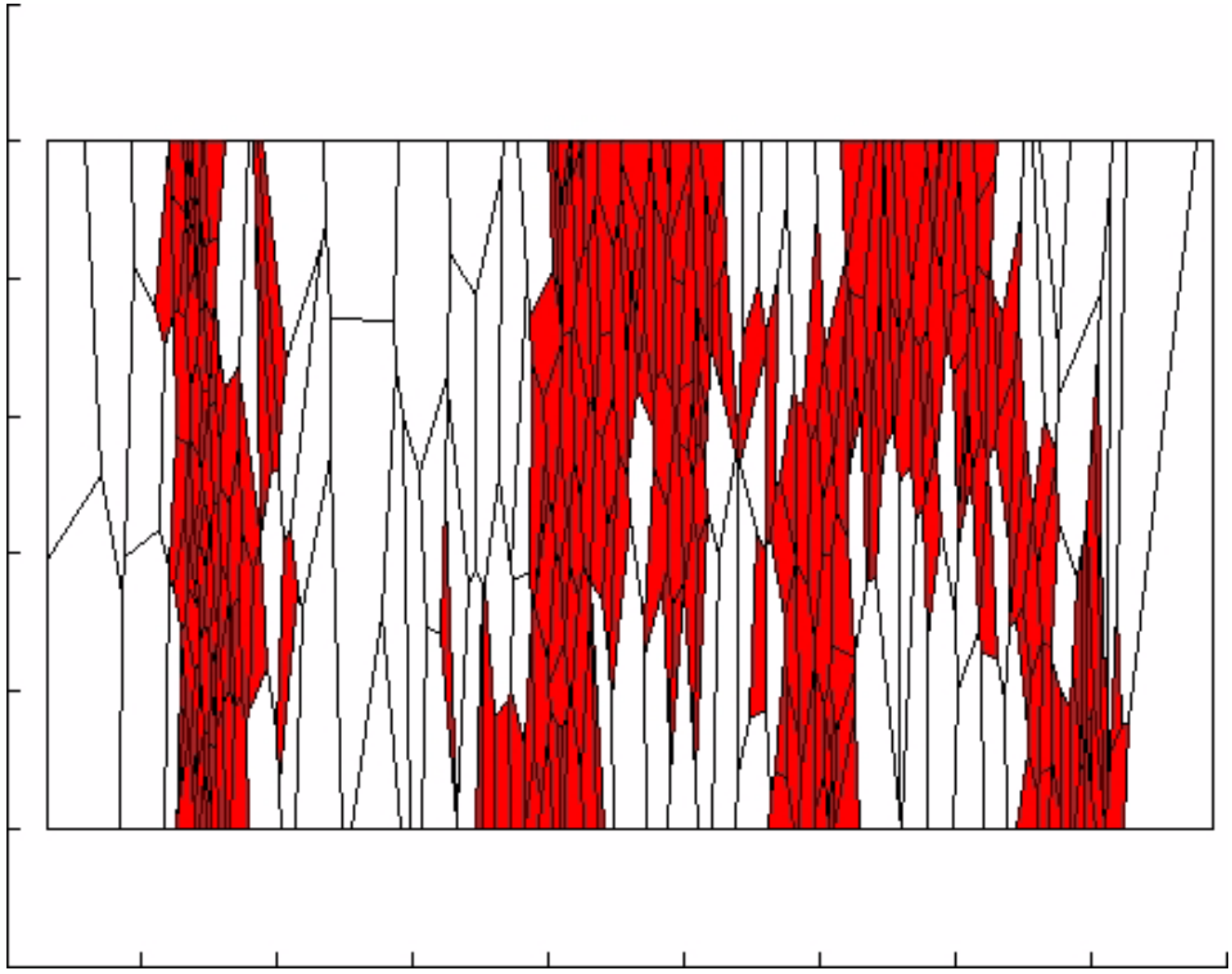
# Conclusion and further work 2/2

- Quantitative analysis
  - Voronoi based space representation
    - MAUP effect reduction
    - Density and free flow speed extraction
  - Issues
    - Small polygons allocated to pedestrians in very dense areas
    - Large polygons allocated to pedestrians at the rims of the groups
    - Human perception is not taken into account
    - Personal polygons overlap with the obstacles

- Future research direction
  - Perception based spatial representation of pedestrian dynamics

# Thank you

# Density – Voronoi space representation



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