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

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13th Swiss Transport Research Conference
Monte Verità / Ascona, April 24-26, 2013
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: $1.2 \text{(ms)}^{-1}$ - $1.8\text{(ms)}^{-1}$
  - Jam-density: $3.8 \text{ped/m}^2$ - $10 \text{ped/m}^2$
  - Maximum flow density: $1.7\text{ped/m}^2$ - $7 \text{ped/m}^2$

- 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
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
Frequently used paths and areas
PIW - peak day
Exploratory data analysis

Qualitative data analysis
Microscopic data analysis
PIW corridor

- 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
Duration – impact of congestion

PIW: zone 12- zone 13

Decrease in the average time: 45%

07:00 – 08:00

10:00 – 11:00
Density – grid space representation

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

- 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
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 perception 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/m²
- 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