Theme Park Mobility in Disaster Scenarios

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1 Motivation

Motivation

- Problem
  - Need for scenario-specific modeling of human mobility
  - Focusing on natural and man-made disasters of theme parks
  - Performance evaluation of the wireless ad hoc networks
  - Various crowd management and evacuation strategies for theme parks can be tested
- Objective
  - Realistic modeling and simulation of human mobility in disaster scenarios

Characteristics of theme parks

- Theme parks consist of attractions which are entertainment places
  - Rides, restaurants, and places for other activities.
- Attractions are connected to each other and to exit points (gates) by road
- Roads are usually used by pedestrians and they have capacities (i.e. width)
- Capacities of roads have effects on pedestrian flows

Modeling the theme park

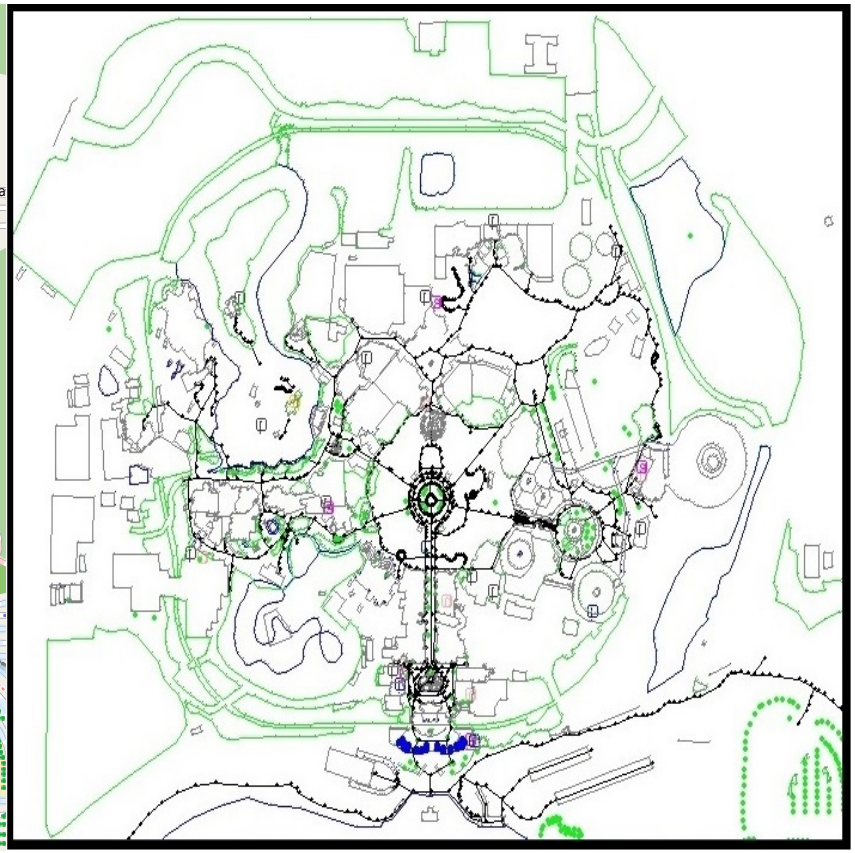
- We model theme parks as the combination of roads, obstacles, lands, and disaster events
- Each road contains a set of waypoints (the movement points for the visitors)
- The gates are considered as the target locations
- Roads show the possible ways to reach the target locations
- Physical obstacles for free movement of the visitors
  - Man-made obstacles: Buildings, fences, walls ...
  - Natural obstacles: Lakes, trees, forest, river ...
- Disaster areas are classified as the circular red-zones
- The red-zones prevent the use of some roads in their active times

Theme park maps

- The model of the theme park can be created synthetically or using real maps
- Using OpenStreetMap (OSM)† to extract the real theme park maps
- Parsing the OSM data to generate the roads, the obstacles, the lands, and the gates.
- The waypoints are collected using the OSM data
- Connecting the consecutive waypoints to create the roads
- Assigning width to the roads according to OSM types (footway, path, and pedestrian way)

†M. Haklay and P. Weber, "OpenStreetMap: User-generated street maps." Pervasive Computing, vol. 7, no. 4, pp. 12?18, Dec. 2008.

Theme park maps

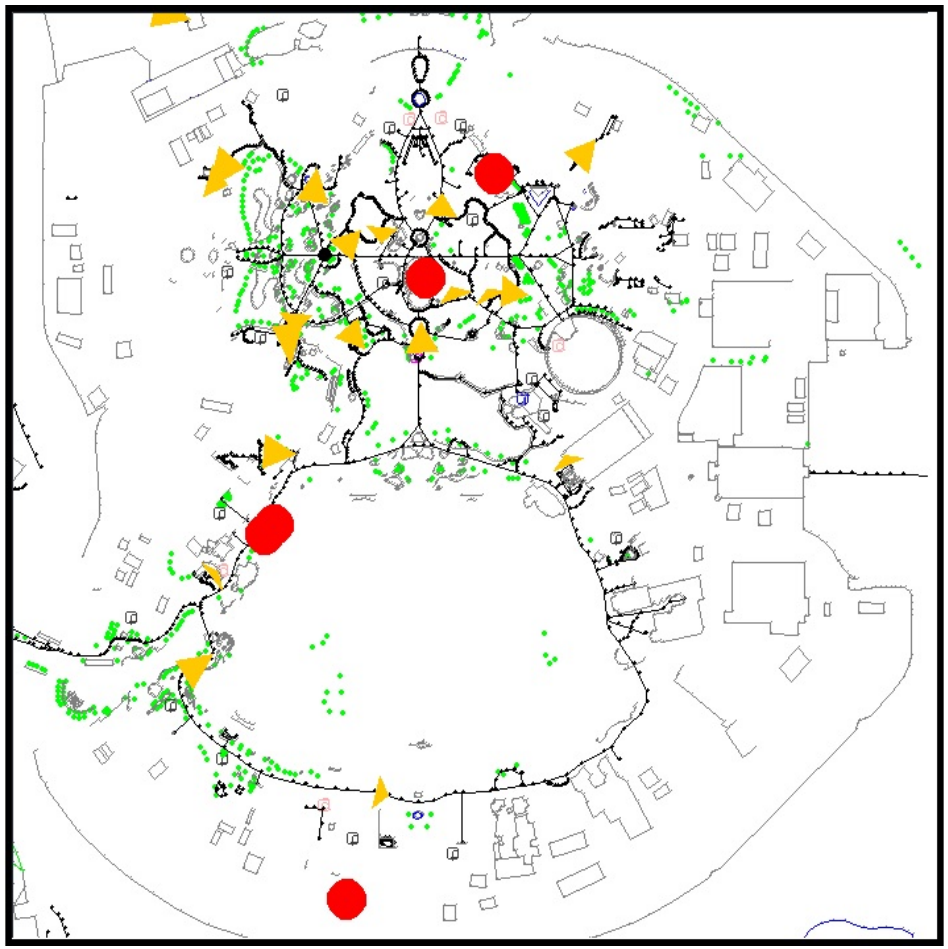


The map of the Magic Kingdom extracted from (OSM) and the processed map with 1300 waypoints (dots)

Macro-mobility

- Each visitor selects an exit gate as a target point
- The visitor tries to reach the target point by moving among the waypoints
- The next destination point is selected among all the visible waypoints
- The visited waypoints or the waypoints in the red-zone are excluded
- The movement along the way is constrained by
  - Knowledge about the world, obstacles and possible active red-zones
- Random exploration if no available waypoint

Mobility of the visitors



Epcot theme park model including 20 visitors (triangles), 2300 waypoints, and 5 red-zones

Mobility of the visitors

- Each visitor has a maximum speed
- Maximum speed depends on physical attributes such as age, gender, and weight
- Maximum speed: The visitor is completely free to walk w/o disturbance or the obstacles
- The actual speed of a visitor is mostly less than the maximum speed
- Due to the effects of the social interactions between visitors

Micro-mobility

- Micro-mobility: the mobility of a visitor between two consecutive waypoints
- Social force model (SFM)† is used for speed and the directions of the movements
- According to the social force concept, behavioral changes in the human are caused by the combination of the social interactions
- We apply this model for the micro-mobility of the visitors

†D. Helbing and A. Johansson, "Pedestrian, crowd and evacuation dynamics," Encyclopedia of Complexity and Systems Science, vol. 16, no. 4, pp. 6476?6495, 2010

Micro-mobility

- Using SFM, we model the social forces on the visitors according to their social interactions with the environment
- Sum of the social forces by the people effects the velocity of a visitor
- The usage of the same roads by the visitors causes an increase in the social interactions
- Increase in the interactions slows down the flow of the visitors along the roads
- Social force model is the best-fit model:
  - Theme parks are crowded areas with roads only used by pedestrians
  - Representing the crowd dynamics and the micro-mobility behavior

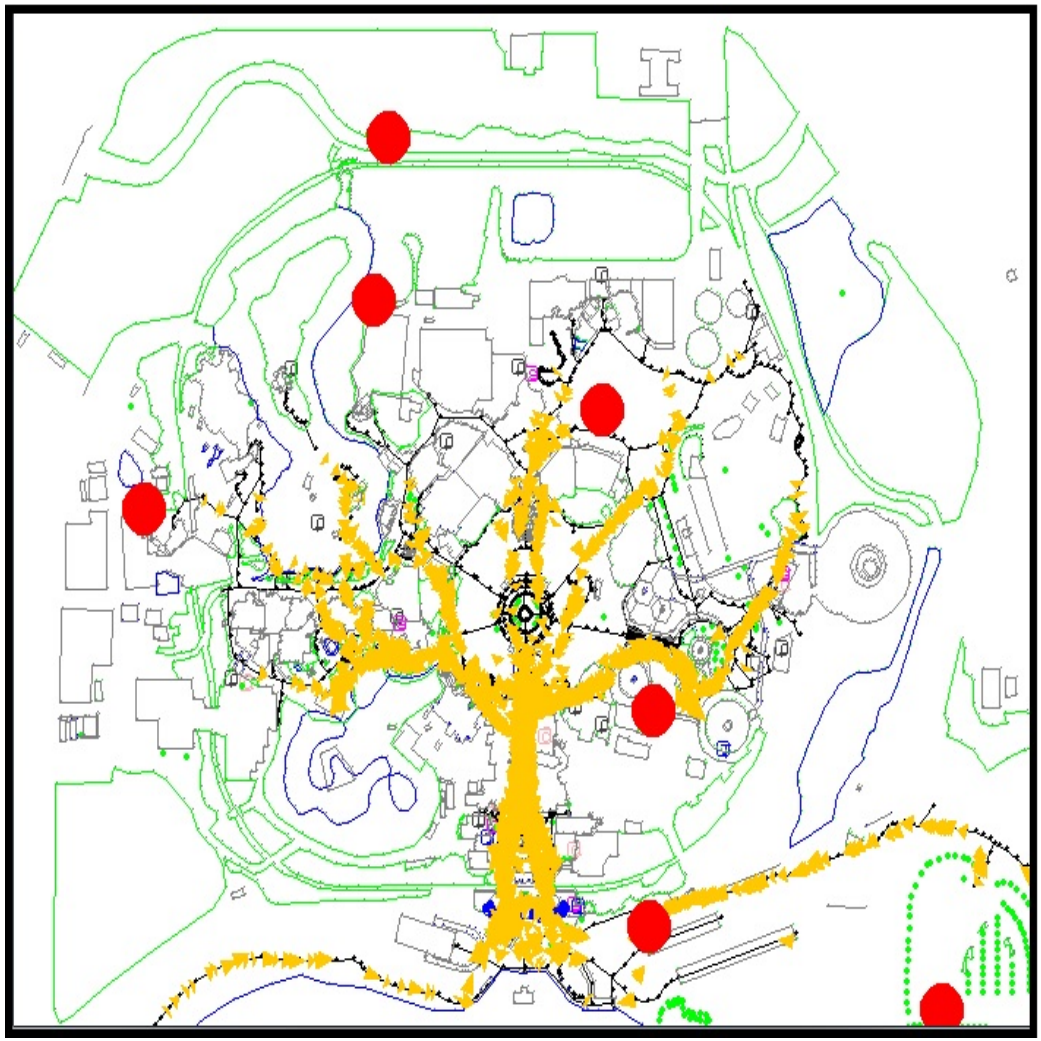
Simulation setup

- TP-D, SLAW, RWP, and GPS traces are compared
- Disaster mobility in Magic Kingdom park is simulated

simulation time	1000s
sampling time	0.5s
number of visitors	1000
min speed	0.5m/s
max speed	2.5m/s
number of red-zones	20
red-zone active time	500s
red-zone radius	50m
visibility	50m

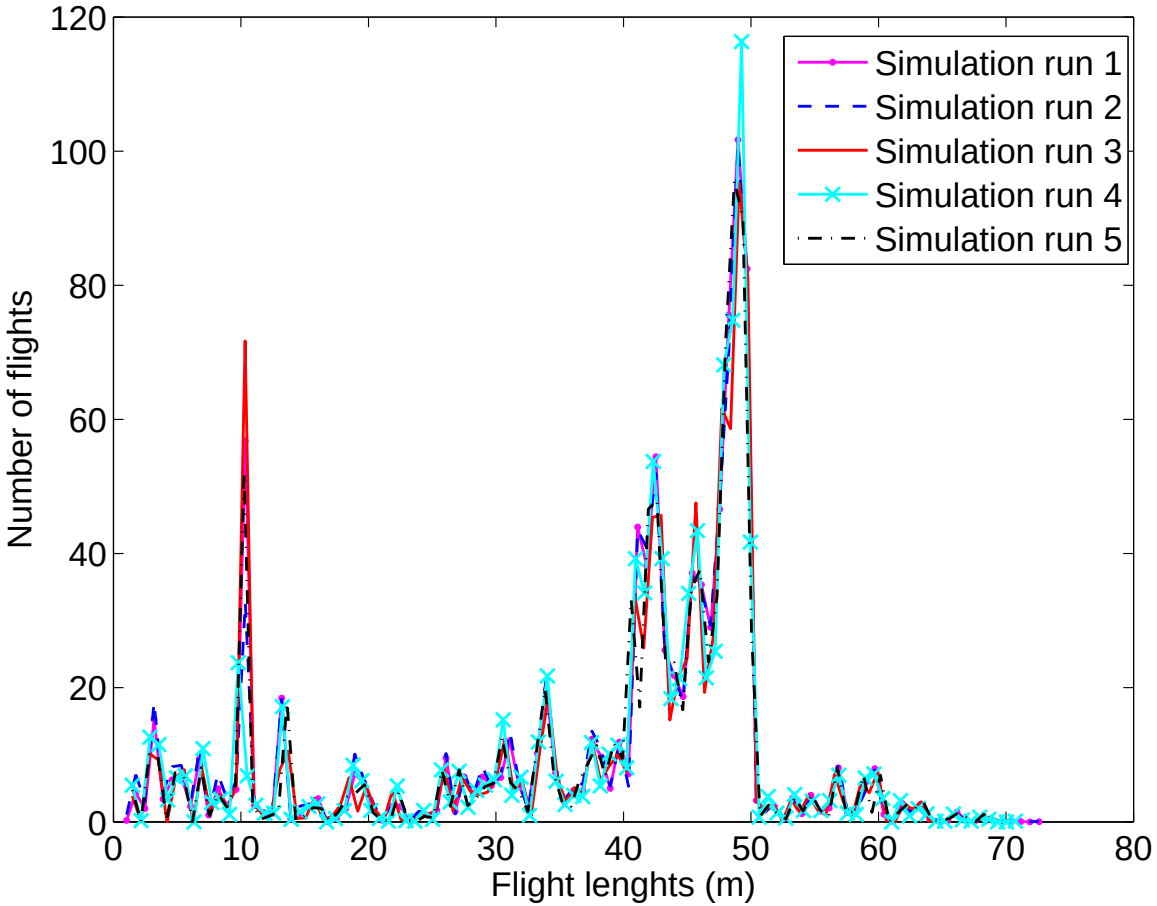
random move distance	10m
SFM - interaction strength (A)	0.11 ± 0.06
SFM - interaction range (B)	0.84 ± 0.63
SFM - relaxation time (τ)	0.5s
SFM - λ	0.1

Simulation setup



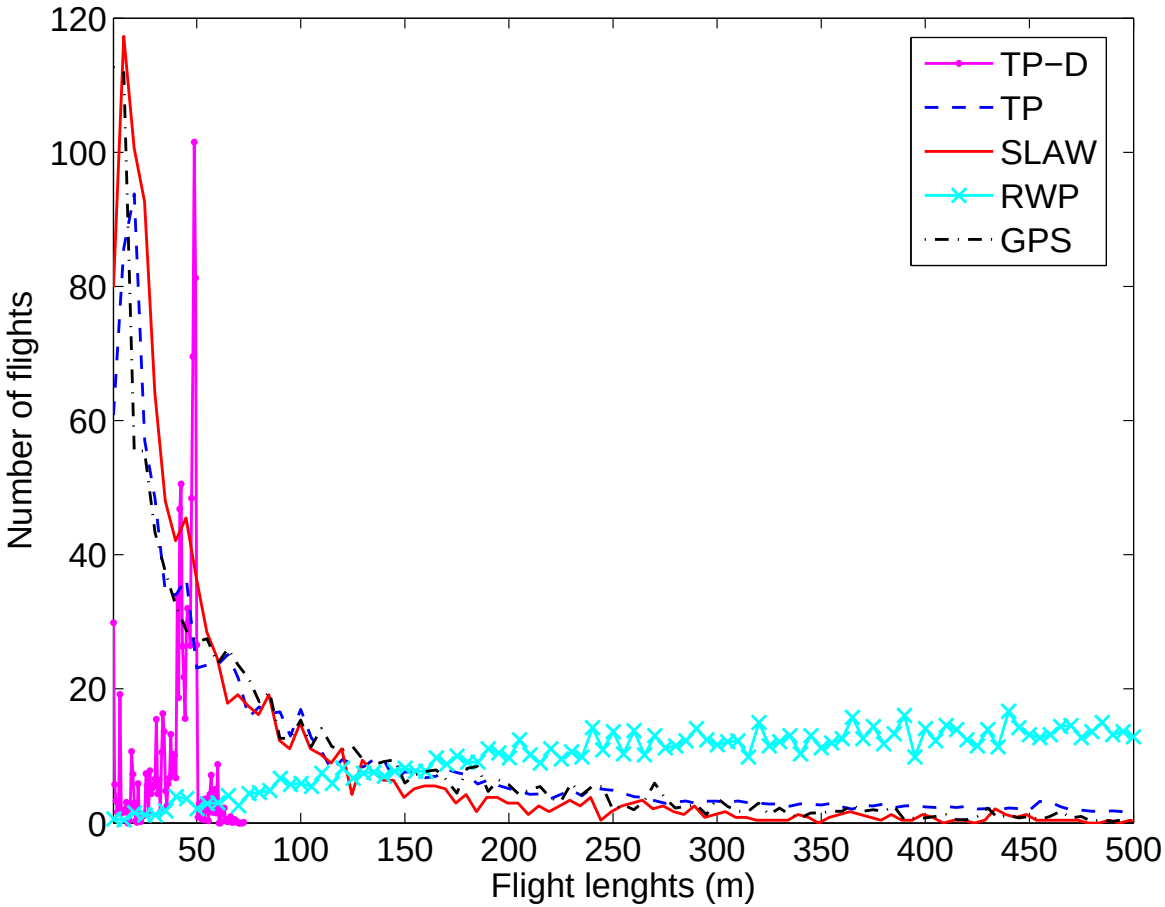
The simulation of 2000 visitors and the impact of red zones in Magic Kingdom

Simulation results



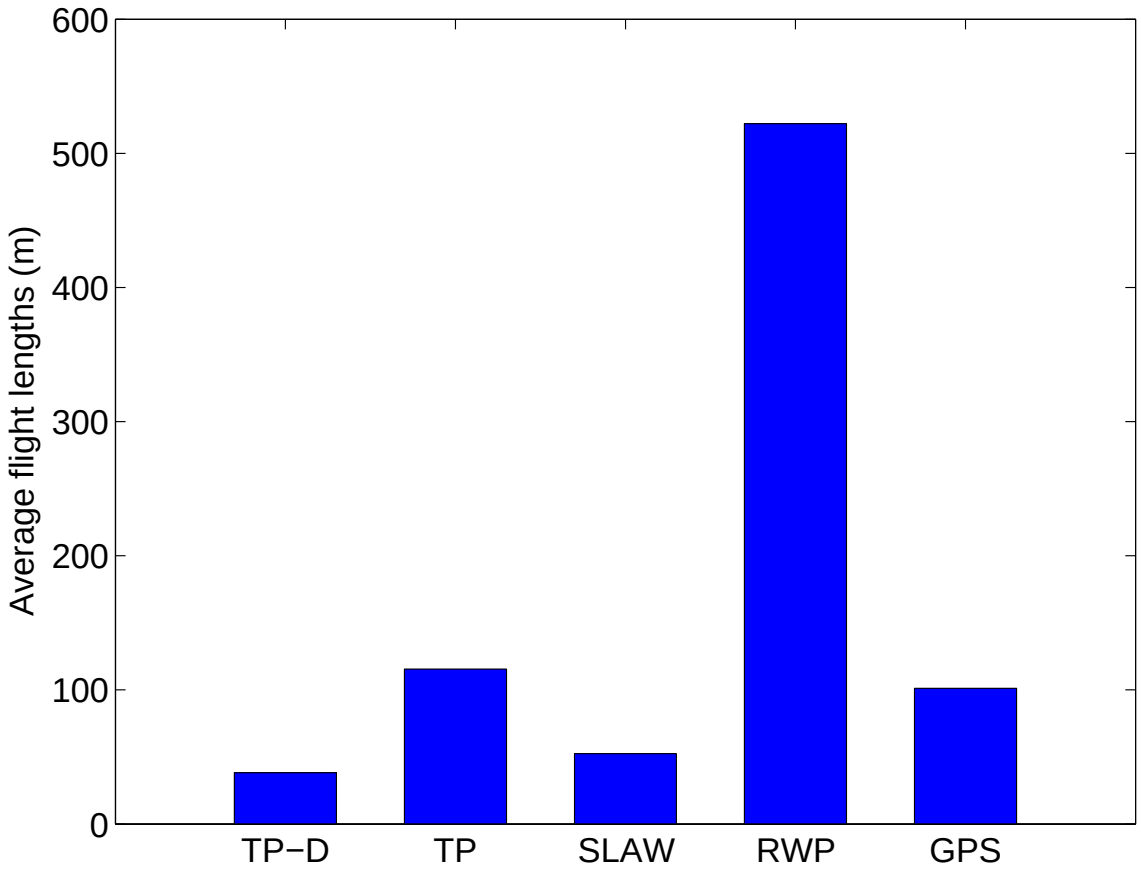
- Consistency of flight length distributions of the TP-D model
- Peak points: visibility and random-move parameters

Simulation results



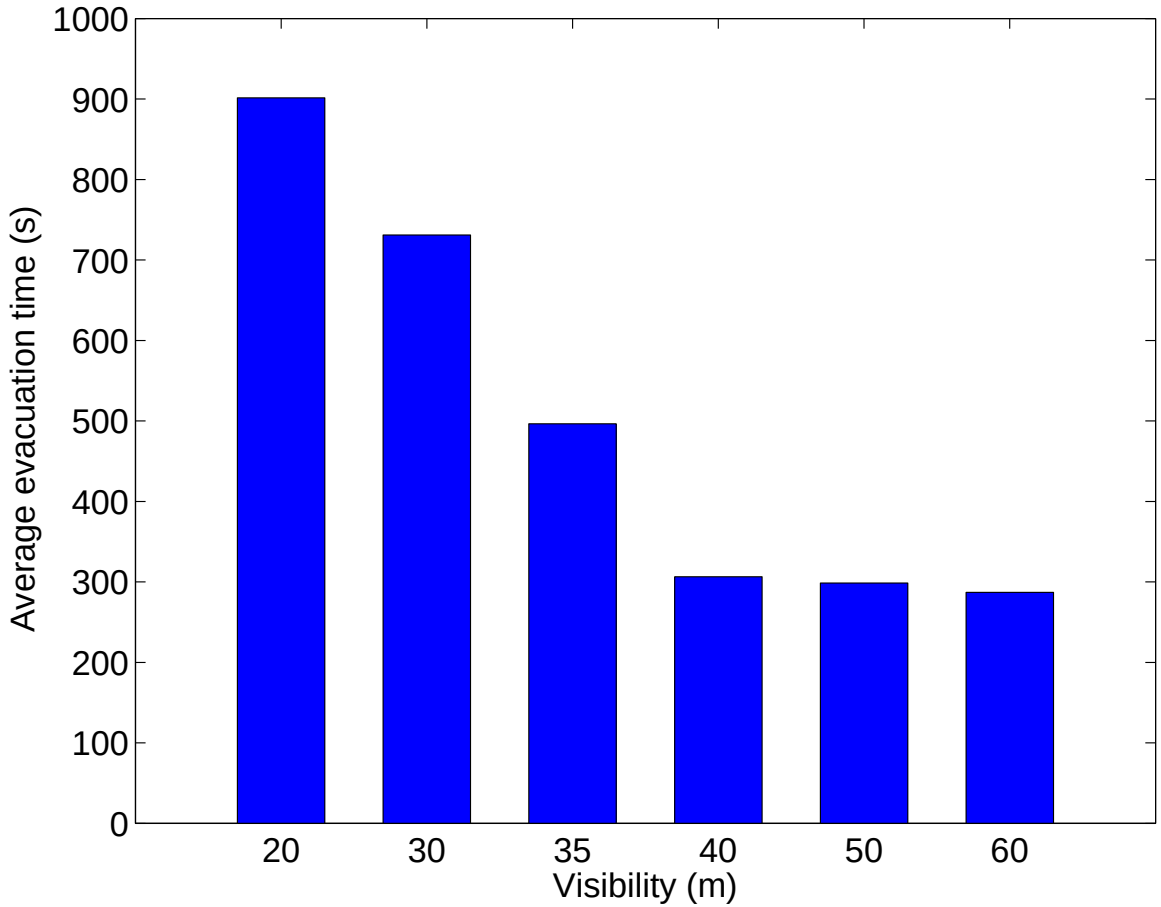
- Flight length distributions for TP-D, TP, SLAW, RWP, and the GPS traces
- Due to local knowledge, long flights w/o pausing is not possible

Simulation results



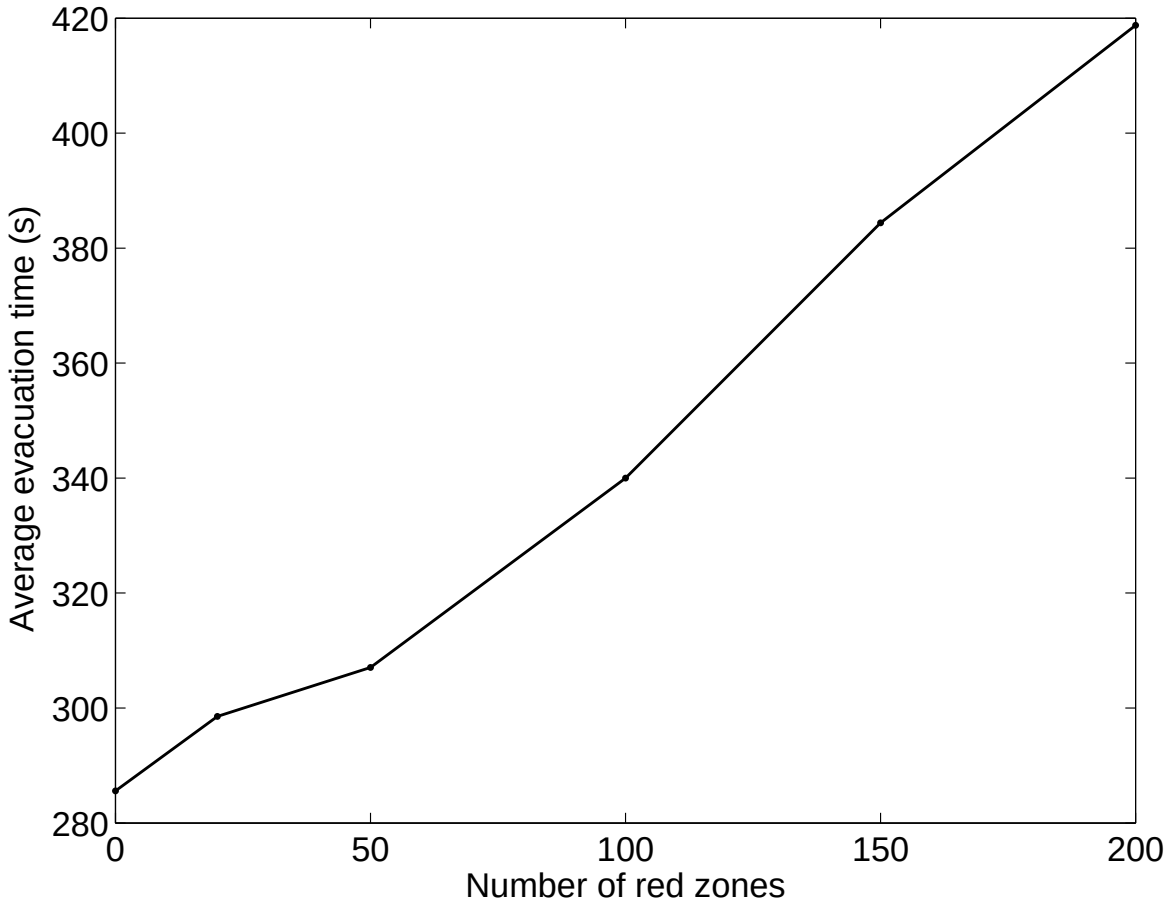
- Shorter flights due to constraints such as visibility, red-zones, and the crowd itself

Simulation results



- Increase in the knowledge causes decrease in evacuation times

Simulation results



- The red-zones prevent the regular flow of the visitors
- Tunneling visitors to other ways increases the average evacuation times

Conclusion

- Proposed a mobility model (TP-D) of the theme park visitors in disaster scenarios
- Used real theme park maps to model the environment
- Visitor movement is modeled using the theme park models and the SFM

Future work:

- Evaluating the performance of WSNs with mobile sinks
- Simulation of evacuation strategies