Modelling, simulation and prediction of city road traffic

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Motivation

Heavy traffic: Analysis and forecasting of traffic jams and travel times

Overview

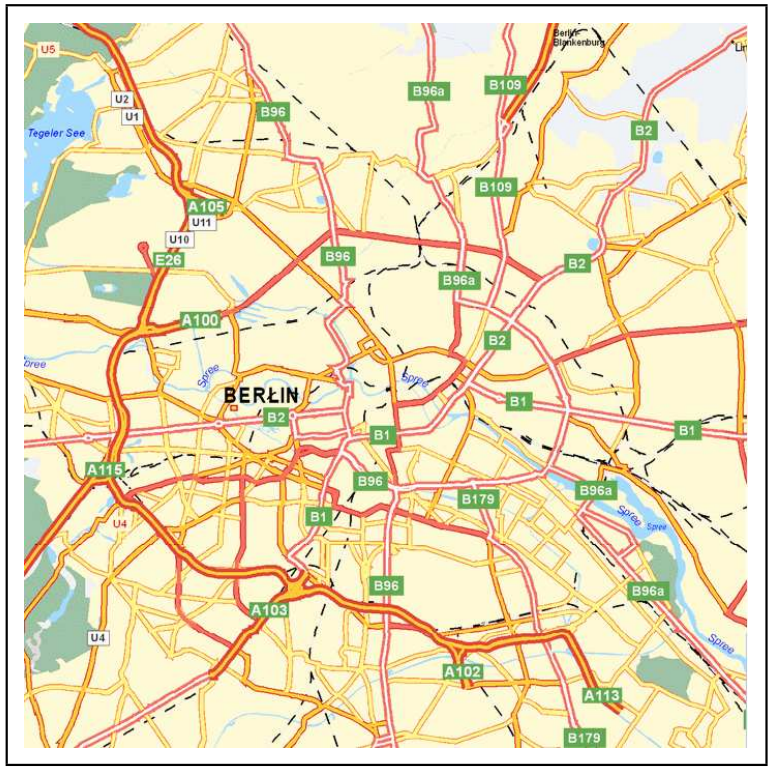
- Traffic data
- Modelling
- Statistical data analysis
- Simulation
- Validation
- Traffic prediction
- Evaluation

Traffic data

Primary traffic control center of Berlin

- 300 test vehicles in down-town Berlin
- GPS traffic data
- Data set with about 13 Mio. entries within three months

Traffic data

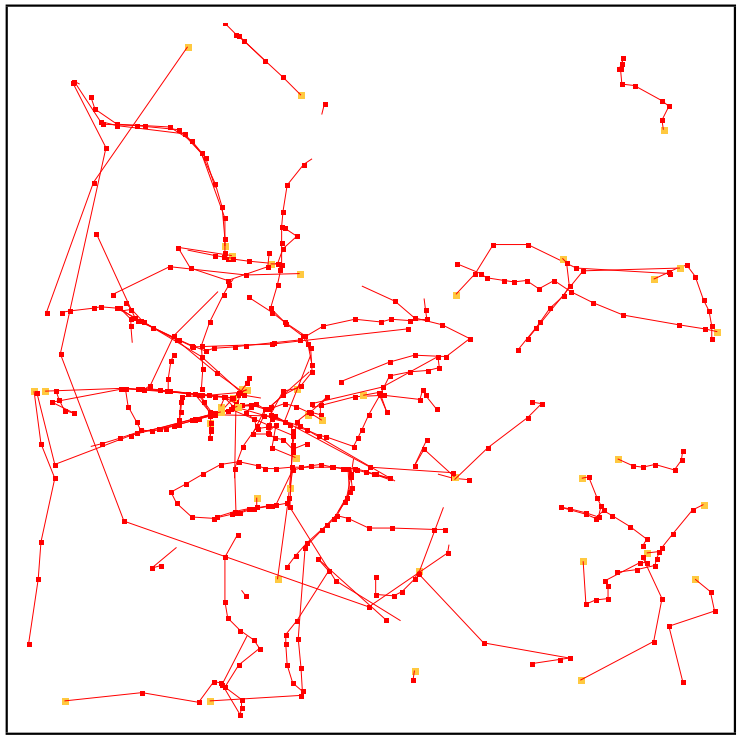


Observed positions of test vehicles in downtown Berlin and the corresponding road map

Modelling

- Goal: Modelling of taxi tracks
- Test vehicles get unique IDs per day
- Create specific tracks in the sampling window
- Tracks are characterized by different parameters like time instants, geographic positions and velocities at GPS locations, number of GPS signals per trajectory, subsequent directions of movement, etc.

Modelling

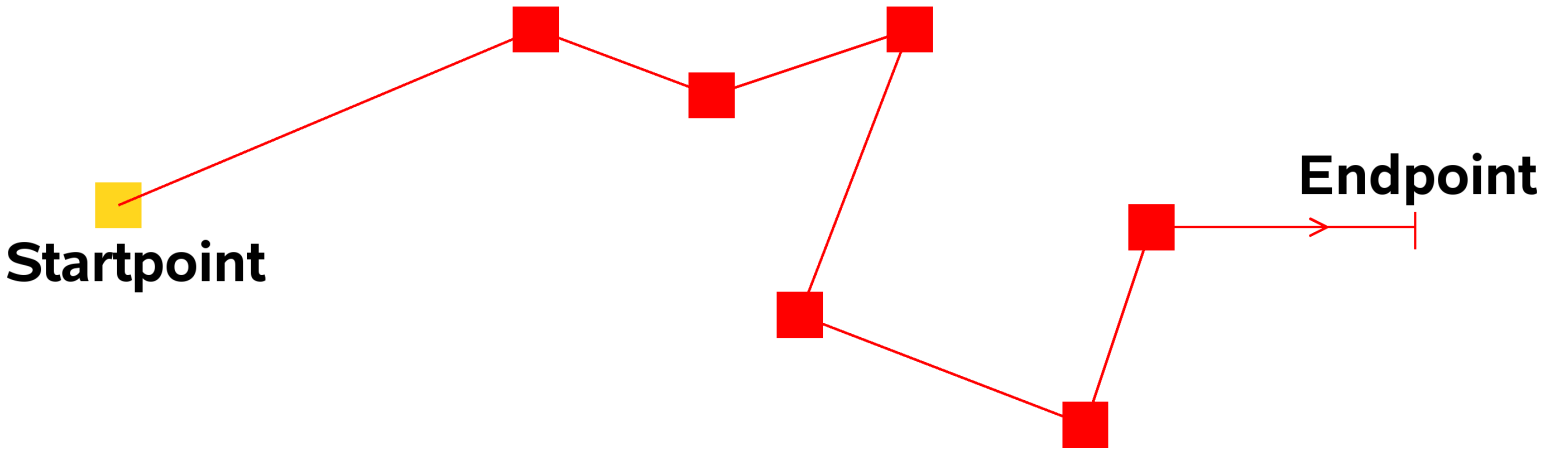


Taxi tracks 02.02.2004, 17:15 - 17:30

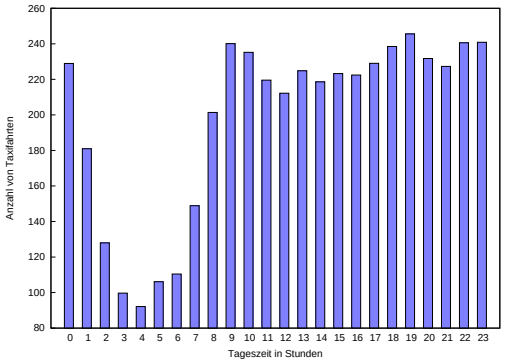
Modelling

Some important parameters of traffic tracks

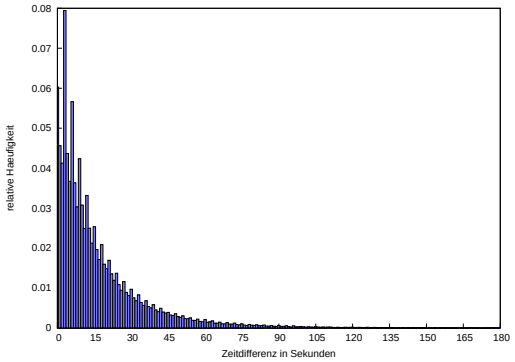
- Initial location and start up direction
- Angle differences to following segments
- Time stamps of GPS signals



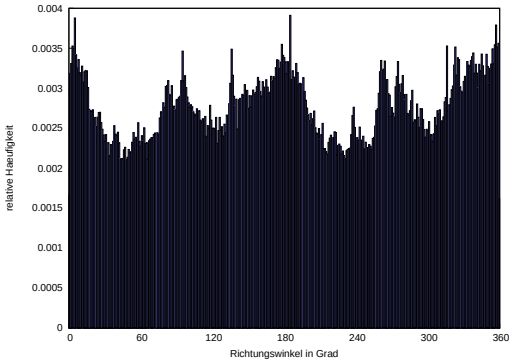
Statistical data analysis



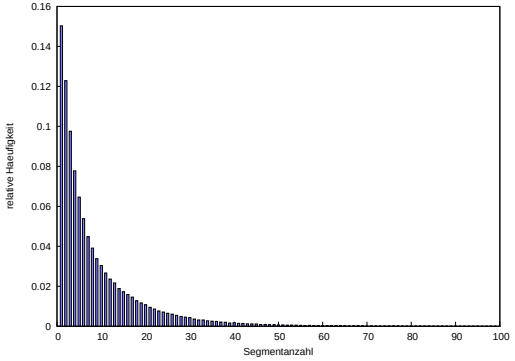
Start up intensities



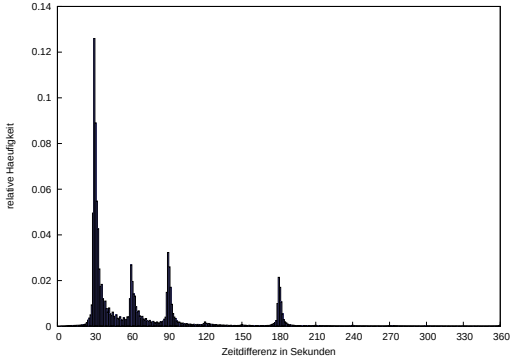
Start time diff.



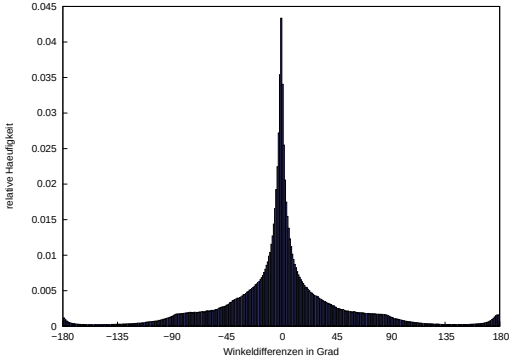
Target directions



No. of segments

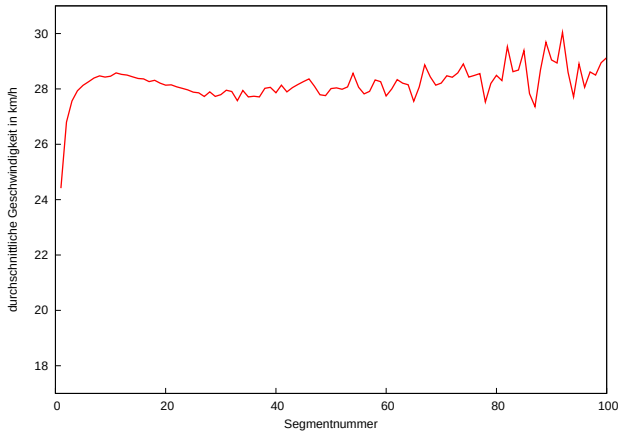


Observ. time diff.

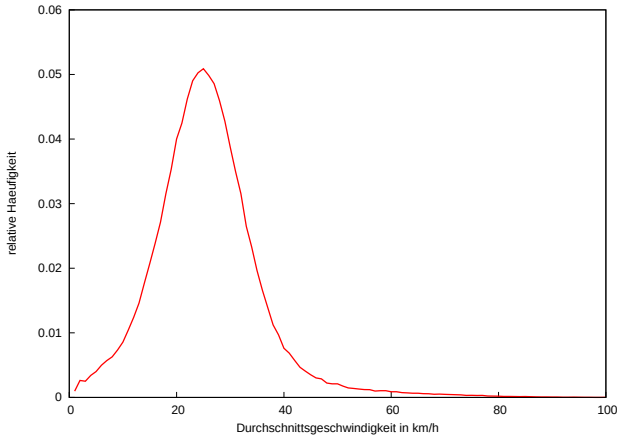


Segment angle diff.

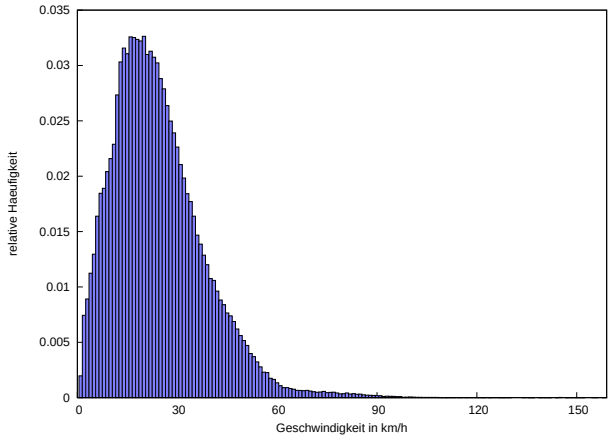
Statistical data analysis



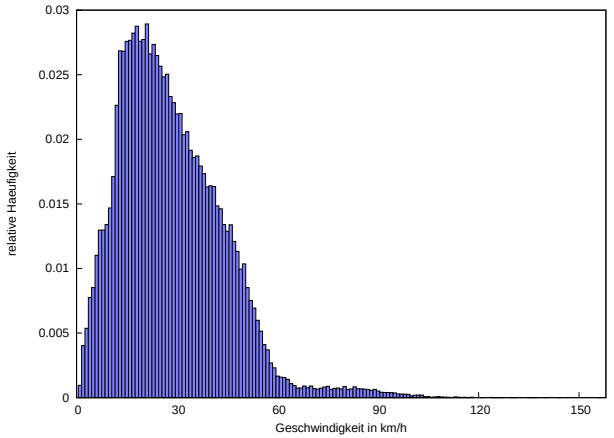
Segment velocities



Mean velocities

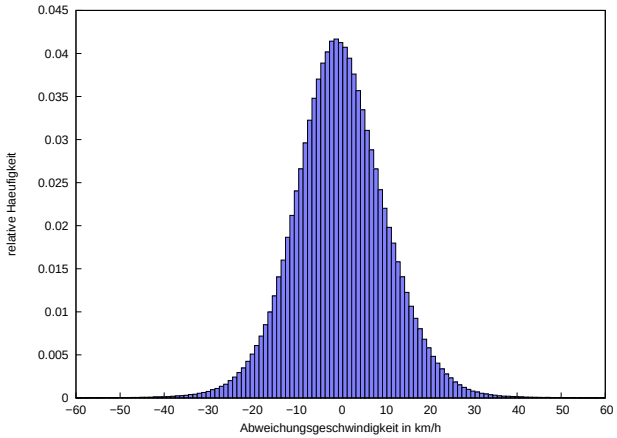


Velocity, 1st segment

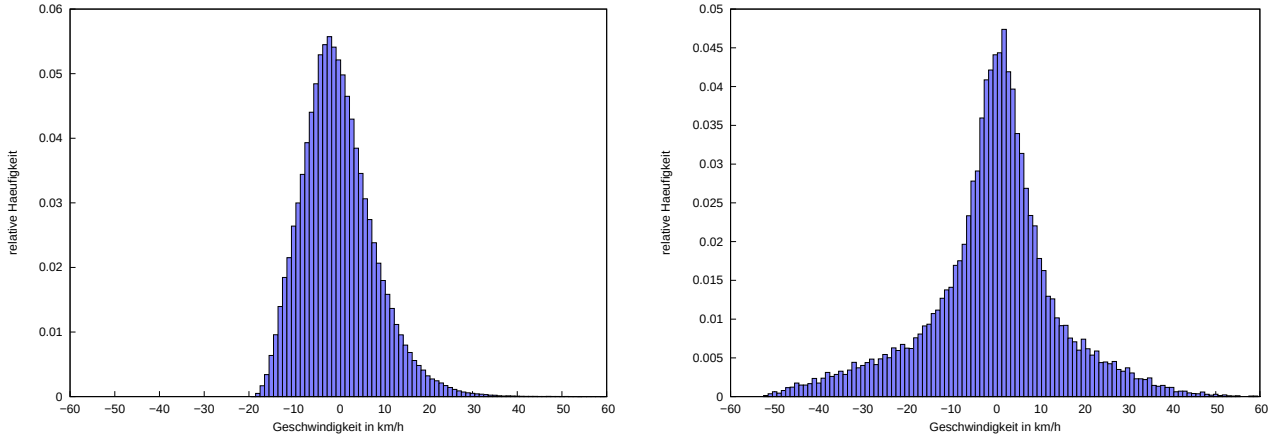


Velocity, 10th segment

Statistical data analysis



Residual velocities



Residual velocities in average classes [15,20) and [50,55)

Modelling

- Start time, start angle and the number of segments are chosen from the corresponding histograms
- Parameters for the segments are chosen similarly
- Velocity and direction angle differences of the segments are chosen in dependence on the mean values and the values of previous segments

Modelling

- Calculation of actual velocities:

  $V_n = \frac{1}{2}(\bar{V}_n + R_n + V_p)$,

  V_p – velocity at the previous segment,

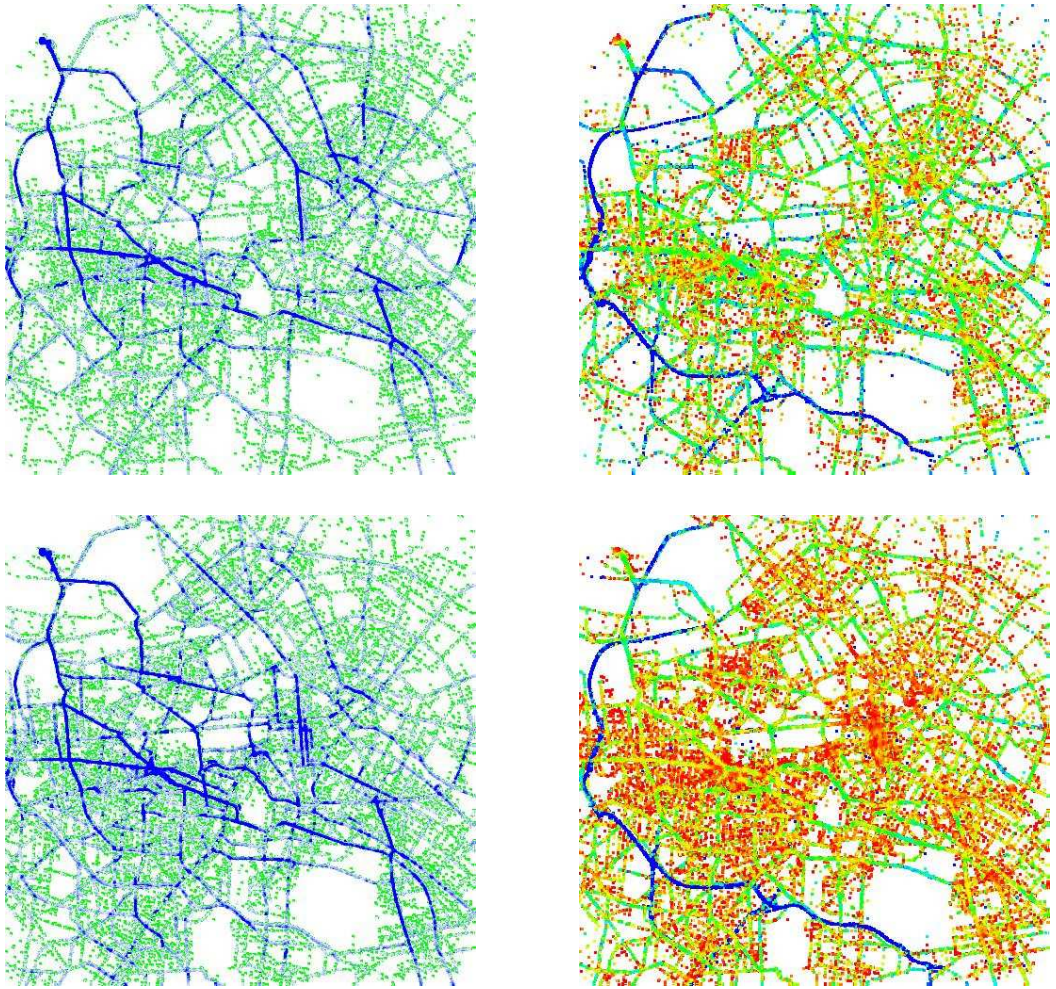
  V_n – velocity at the next segment,

  $\bar{V}_n$ – mean velocity at the next segment,

  R_n – deviation velocity at the next segment.

- $\bar{V}_n$: Average velocities for all positions of the sampling window and for different time slots (velocity maps)

Modelling



Observation frequencies and mean velocities

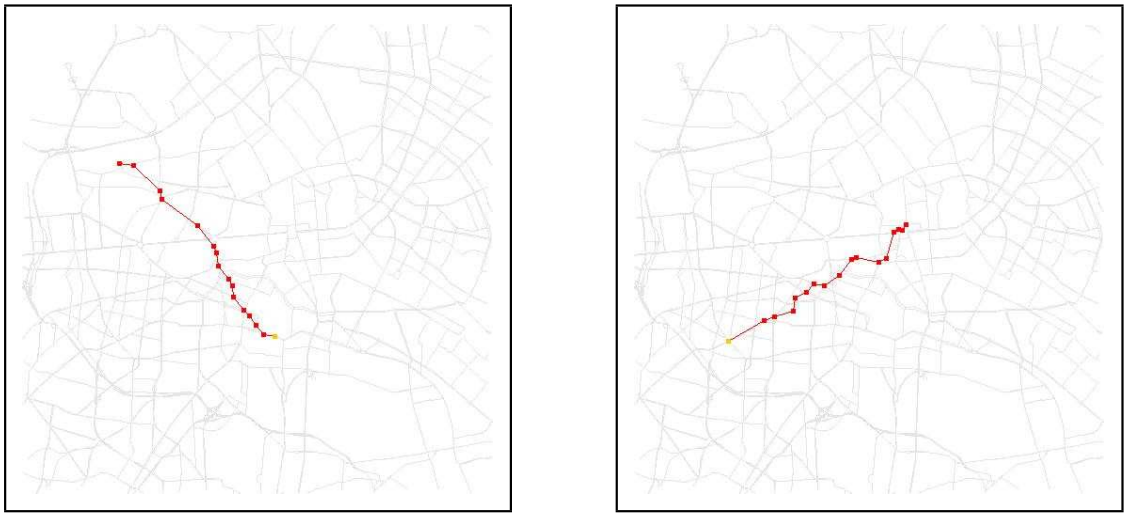
3:30 – 5:30 and 12:30 – 14:30

Modelling

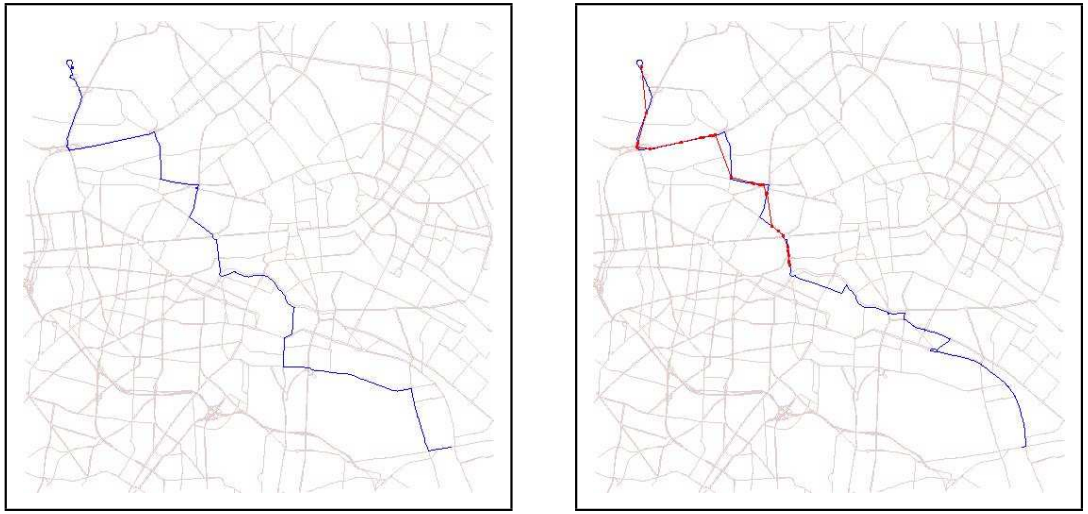
Two principal possibilities:

- Without the road network: Simulation of vehicle tracks as random polygons defined by the above parameters
- On the road network:
  - Searching a path on the road graph from the starting location to a target point by means of ant algorithms
  - Generating a vehicle track along this path

Simulation



Examples of simulated vehicle tracks ignoring the road network



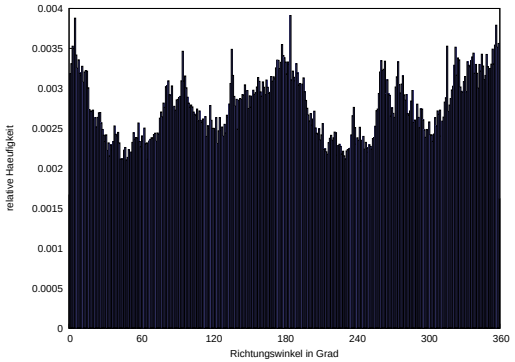
Searching a path on the street graph and fitting a vehicle track to this path

Simulation

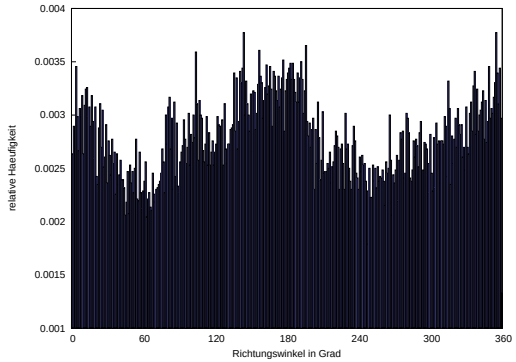
Used ant systems:

- Classical ants: all paths are weighted equally
- Elite ants: the best path gets the largest weight
- Rank–based ants: only n best paths are taken into account. The best path gets the largest weight, the second best one gets a smaller weight, and so on.

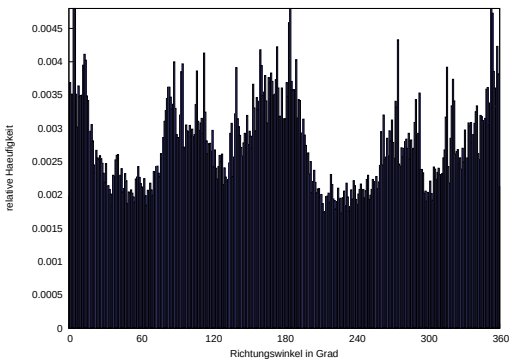
Validation



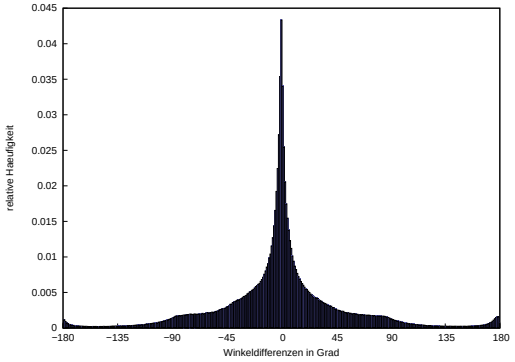
Target direction



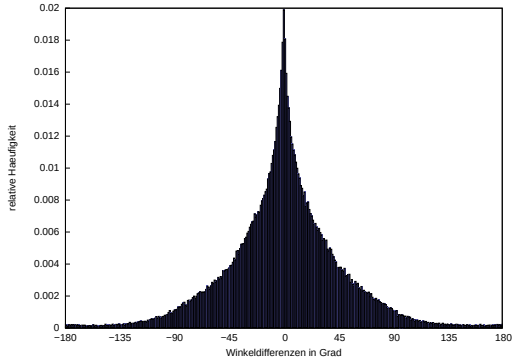
Simulation without the road network



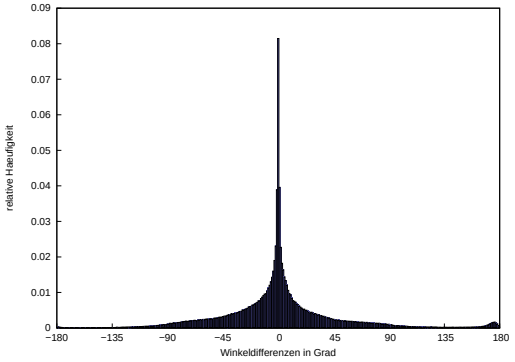
Simulation on the road network



Direction angle diff.

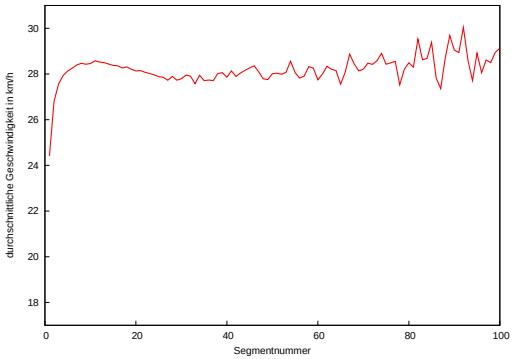


Simulation without the road network

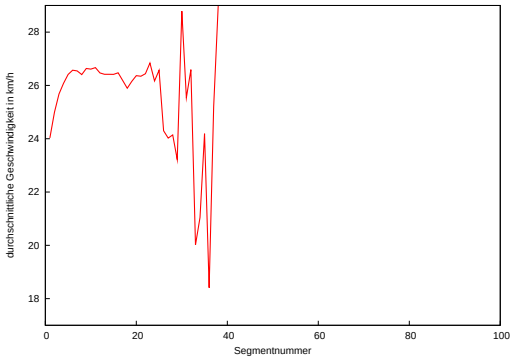


Simulation on the road network

Validation



Velocities



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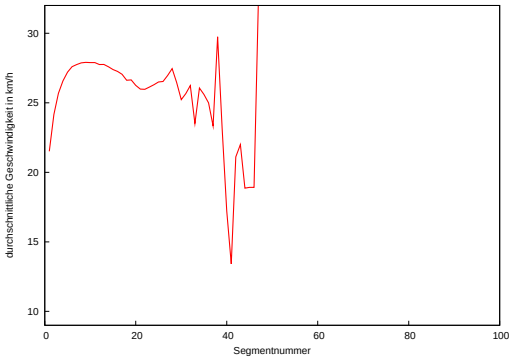

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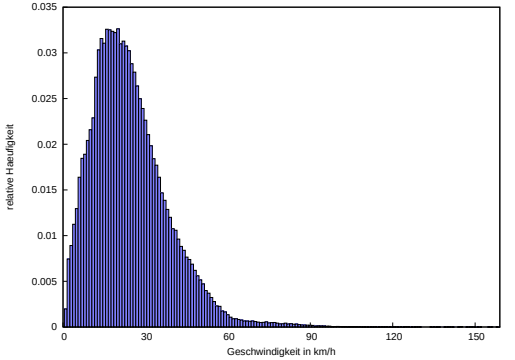
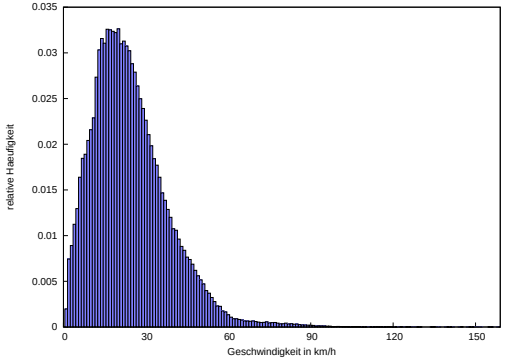
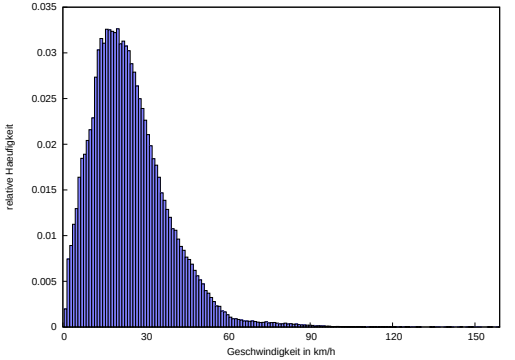


Velocities, 1st segment



Simulation without the road network

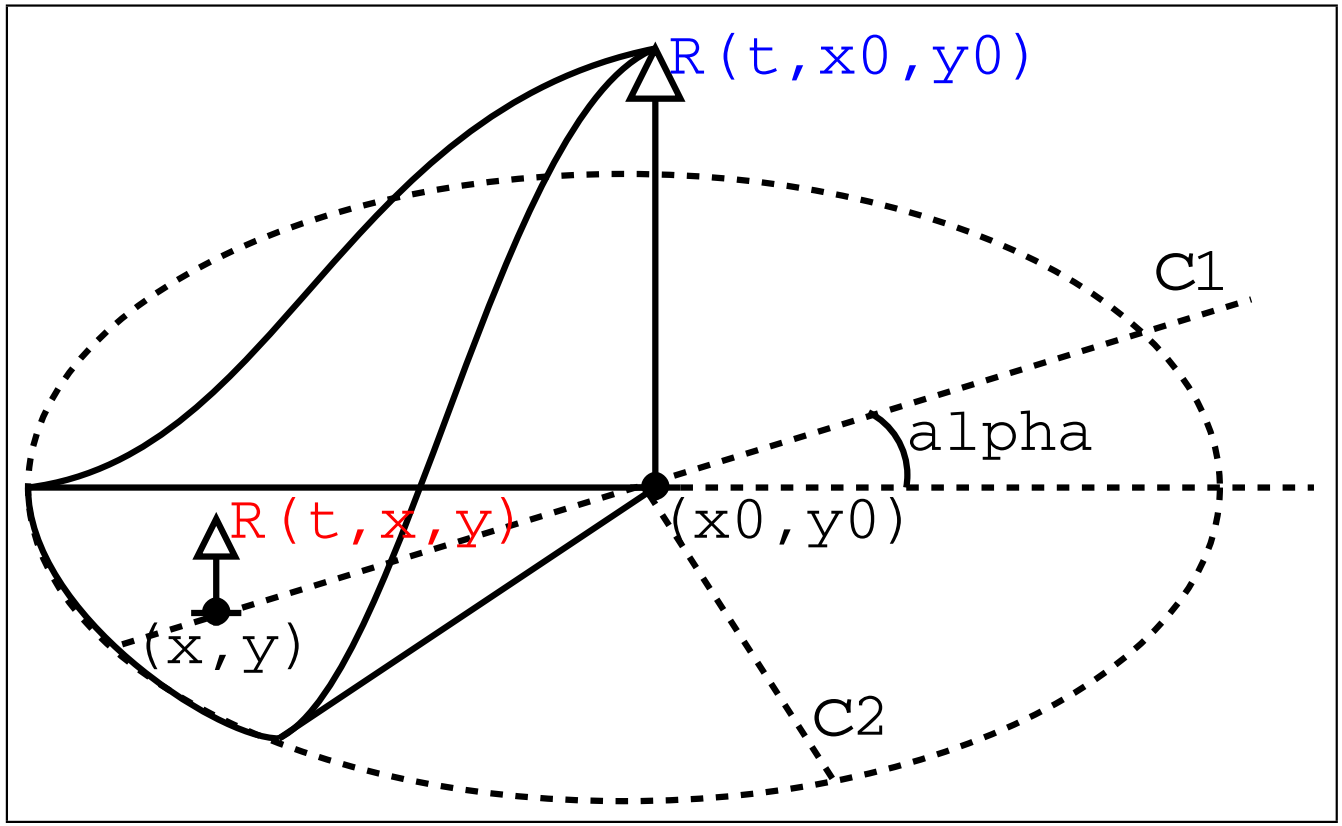


Simulation on the road network

Traffic forecasting

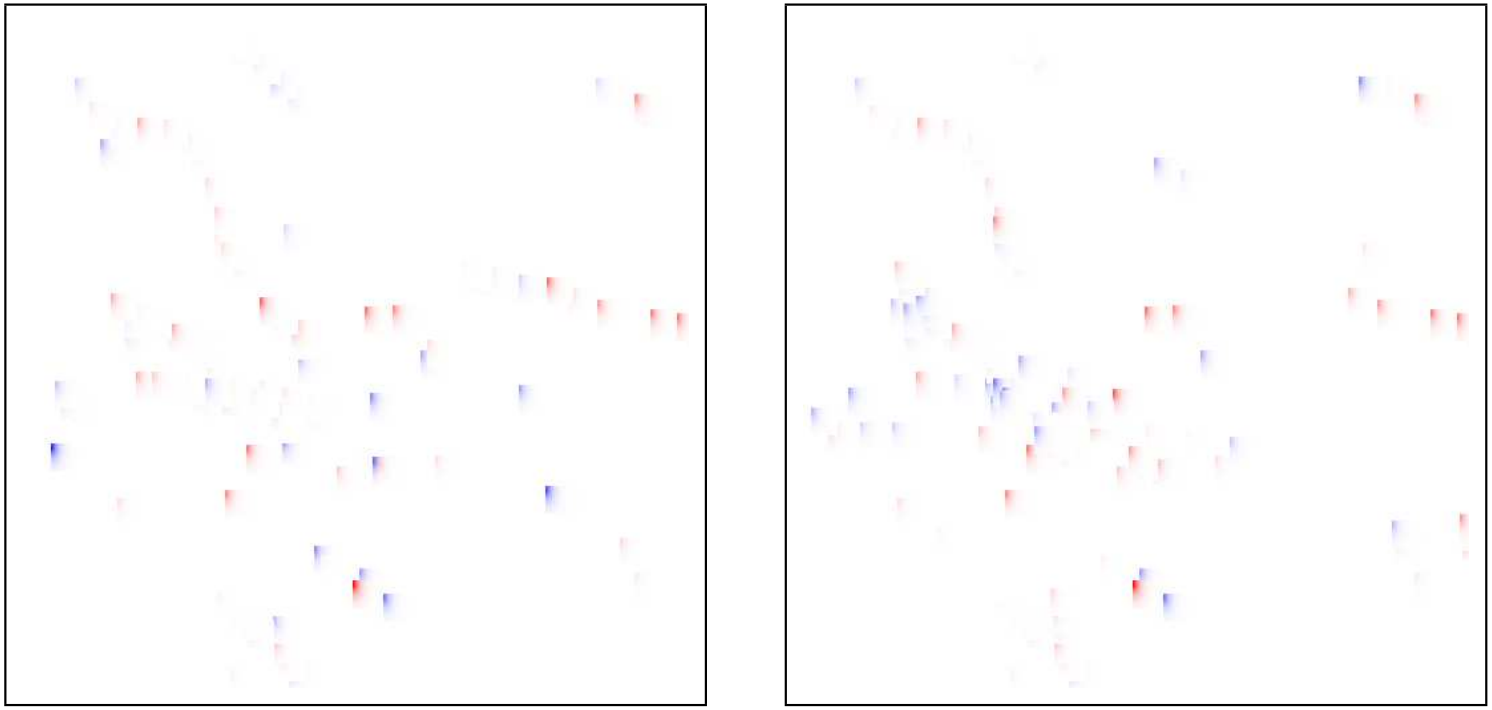
- Conditional simulation of traffic tracks
- Splitting the data into four independent direction sectors
- Calculating the range of influence of vehicles for each sector
- Determining deviation velocities (from the mean) of historical and simulated data

Traffic forecasting



Calculating the range of influence of a vehicle

Traffic forecasting



Areas of influence of historical and simulated data (positive (blue) and negative (red) deviation velocities)

Evaluation

- Evaluation: Simulating 1000 traffic scenarios with a simulation time of 5, 10, 15 and 20 minutes
- Samples: 1000 images from simulated data, 72 images from historical data (traffic maps on working days) and one reference image $\longrightarrow$ Building difference and threshold images to compare real and simulated traffic scenarios

Evaluation

- Comparing images: Mean, variance, Minkowski functionals and other image metrics
- Minkowski functionals can only be evaluated for binary images $\longrightarrow$ Transform color or gray scaled images to binary images
- Calculating area, boundary length and Euler–Poincaré characteristic (number of clumps minus number of holes)

Results and outlook

- Stochastic traffic forecasting up to 15 min. into the future is possible
- Adjustment of modelling parameters can increase the overall performance
- Validation of the goodness of traffic simulation
- Testing the software on the road data of other large cities
- Using the software in the project "Traffic tower"

References

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- *Kriged road-traffic maps*, in: Interfacing Geostatistics, GIS and Spatial Data Bases. Proceedings of the International Conference StatGIS03, J. Pilz (Ed.) Springer Series: Advances in Spatial Science, Berlin (2005), 39-50.
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- *Algorithms for the computation of Minkowski functionals of deterministic and random polyconvex sets*, Image and Vision Computing 25 (2007), 464-474.

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