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# An Extendable Framework for Managing Uncertain Spatio-Temporal Data

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## In a Nutshell

This demonstration presents our uncertain-spatio-temporal (UST-) framework that we have developed in recent years. The main research focus of this UST-framework is the explicit consideration of uncertainty in spatio-temporal data. The UST-framework can be used to obtain a deeper intuition of the quality of spatio-temporal data models. Such models aim at estimating the position of a spatio-temporal object at a time where the object's position is not explicitly known, by using both historic (traffic-) pattern information, and by using explicit observations of objects.

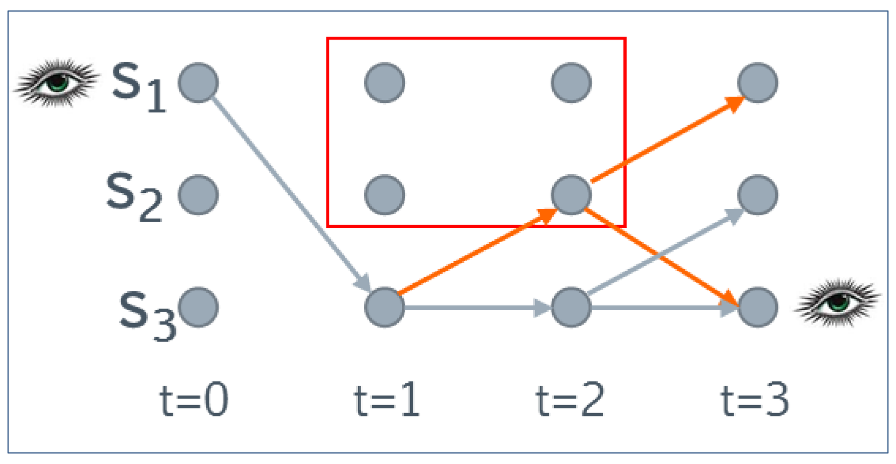
The UST-framework illustrates the resulting distributions by allowing a user to move forth and back in time. Additionally, the framework allows users to specify simple spatio-temporal queries, such as spatio-temporal window queries and spatio-temporal NN-queries. Based on recently published theoretic concepts, the UST-framework allows the user to visually explore the impact of different models and parameters on spatio-temporal data. The main result showcased by the UST-framework is a convincing minimization of uncertainty by employing stochastic processes, leading to small expected distances between ground truth trajectories and modelled positions.

## Theory

- Model spatio-temporal objects as stochastic processes.
- Family of Random variables (X)t parameterized over time.
- Estimate the position of an object at a time *t* where the exact position of an object is not explicitly stored in the database.
- Maximum Likelihood Estimation using
  - Observations of objects
  - Empiric knowledge of traffic patterns

## Bayesian Learning

Condition a Markov-Model to observations in the past and in the future




Compute a-priori state probabilities in a forward-step.

Use a-priori knowledge to obtain adapted a-posteriori probabilities given all observations.

$$P(\blacksquare \mid \text{👁}) = \frac{P(\text{👁} \mid \blacksquare) * P(\blacksquare)}{P(\text{👁})} = \frac{P(\blacksquare \wedge \text{👁})}{P(\text{👁})}$$

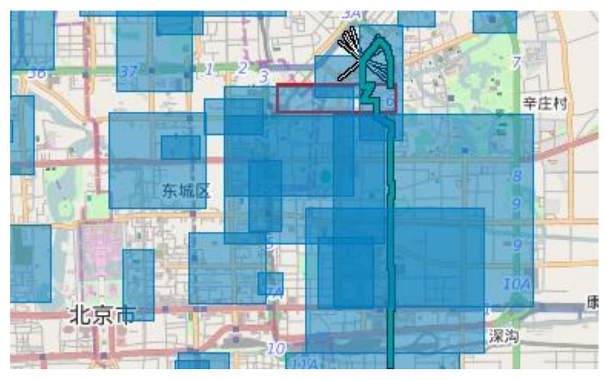
$$= \frac{P(\blacksquare \wedge \text{👁})}{P(\text{👁} \wedge \blacksquare) + P(\text{👁} \wedge \neg \blacksquare)}$$

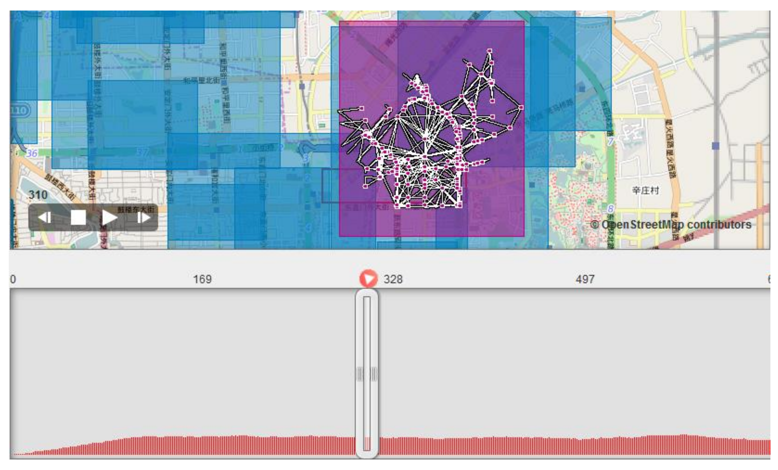
Fusion of Data Sources:

- Empiric traffic information stored in the a-priori Markov Chain
- Concrete observations of individual objects
- Yields a new model adapted to observations, describing unknown detours by empiric knowledge.

## The Framework

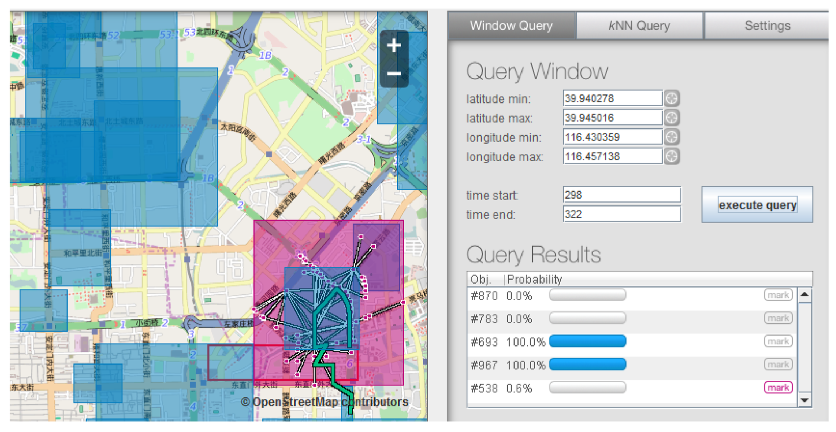
- Visualize Spatio-Temporal Data

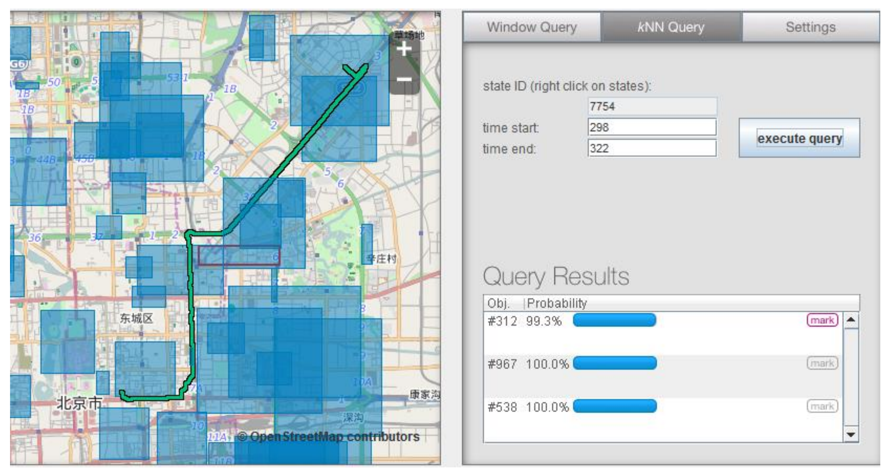




- Explore different interpolation models
  - Linear and Shortest-Path Interpolation
  - Geometric Models, e.g. [4]
  - Markov Models [1]
  - Bayesian Markov-Chain Adaption Model [3]
- Index support for query processing [2]
- Visualization of Query Results

- Window Queries

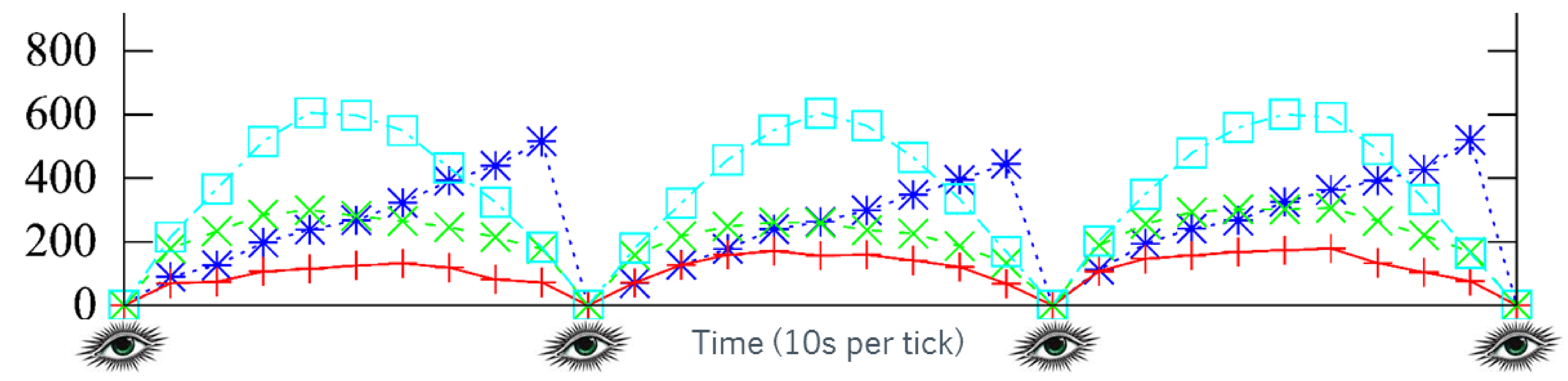




- Nearest-Neighbor Queries

## Model Evaluation

Evaluation of expected distances to the ground truth trajectory




+ A-posteriori Markov model
* A-priori Markov model
× A-posteriori Markov model without a-priori knowledge
□ Spatio-Temporal approximations (competitor approach)

[1] T. Emrich, H.-P. Kriegel, N. Mamoulis, M. Renz, and A. Züfle. Querying uncertain spatio-temporal data. In ICDE'12, pp. 354-365.

[2] T. Emrich, H.-P. Kriegel, N. Mamoulis, M. Renz, and A. Züfle. Indexing uncertain spatio-temporal data. In CIKM'12, pp.395–404.

[3] J. Niedermayer, A. Züfle, T. Emrich, M. Renz, N. Mamoulis, L. Chen, and H.-P. Kriegel. Probabilistic nearest neighbor queries on uncertain moving object trajectories. In VLDB, 2014.

[4] G. Trajcevski, O. Wolfson, K. Hinrichs, and S. Chamberlain. Managing uncertainty in moving objects databases. ACM Trans. Database Syst., 29(3):463–507, 2004.

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