AALBORG UNIVERSITY

Challenges in the Tracking and Prediction of Scheduled-Vehicle Journeys

Dalia Tiešytė, Christian S. Jensen,
{dalia,csj}@cs.aau.dk

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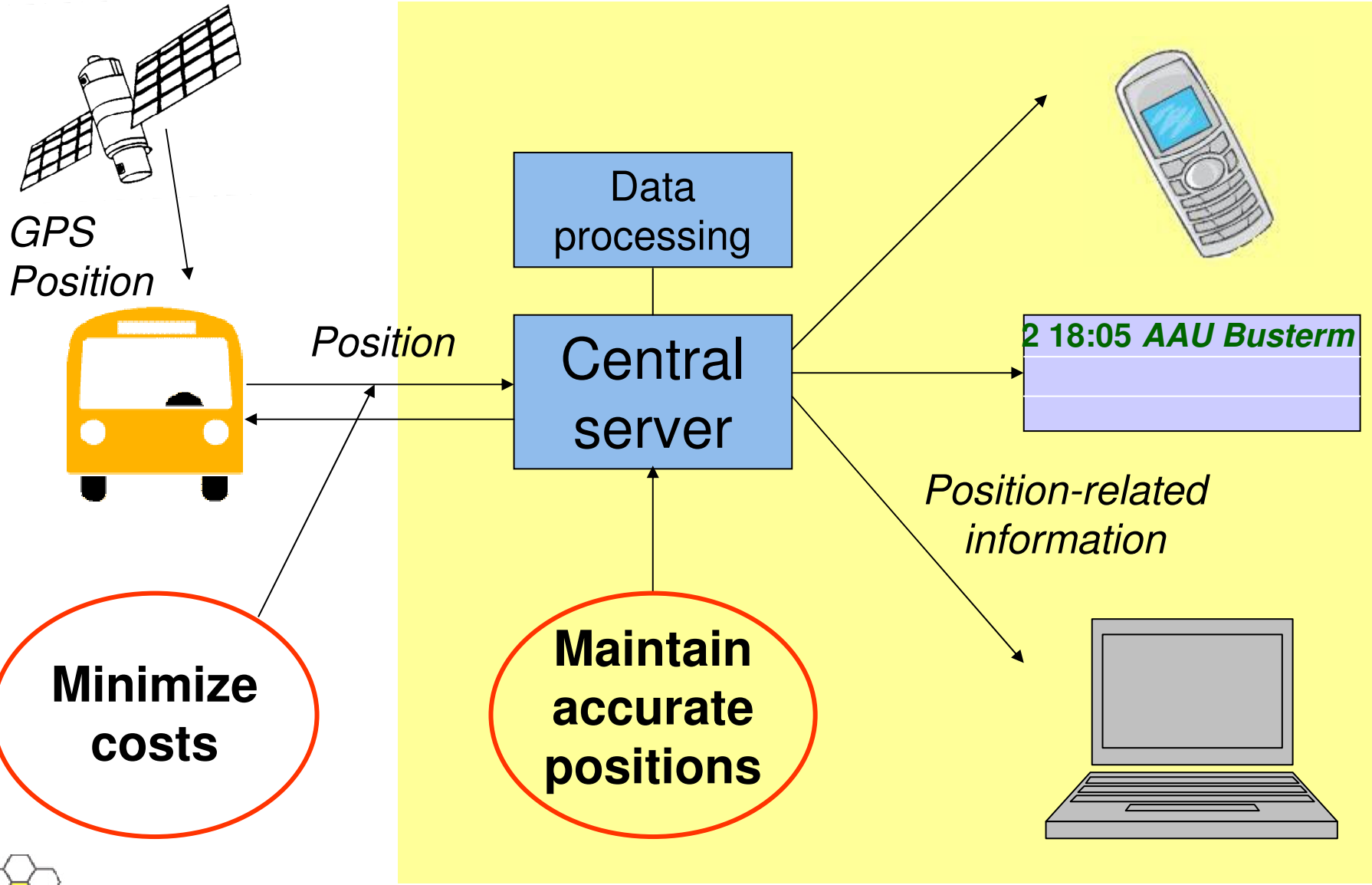
Scenario


GPS
Position
Position
Data
processing
Central
server
2 18:05 AAU Busterm
Position-related
information
Minimize
costs
Maintain
accurate
positions

Roadmap

- Introduction
  - State of the art
  - Room for improvement
- Challenges
  - Efficient tracking algorithms
  - Accurate prediction algorithms
  - Analysis of historical data
- Conclusion

State of the Art

- Tracking algorithms
  - Shared prediction function [Čivilis et al. 2005, Wolfson et al. 2003]

$$pos(t) = f(pos_{up}, t - t_{up}, v_{up})$$

Vector-based, road network-based, route-based tracking

- Travel time prediction algorithms for scheduled vehicle journeys
  - Kalman filter [Cathey and Dailey 2003, Shalaby and Farhan 2001, Dailey et al. 2004]
  - Artificial Neural Networks [Chien et al. 2002, Park et al. 2004, Hee and Rilett 2004]

Room for Improvement

What?

- Higher position accuracy on the server side.
- Lower operational costs.
- More precise schedules.

How?

- Use all available data (historical trips, real-time data, external data).
- Communication when and only when required.

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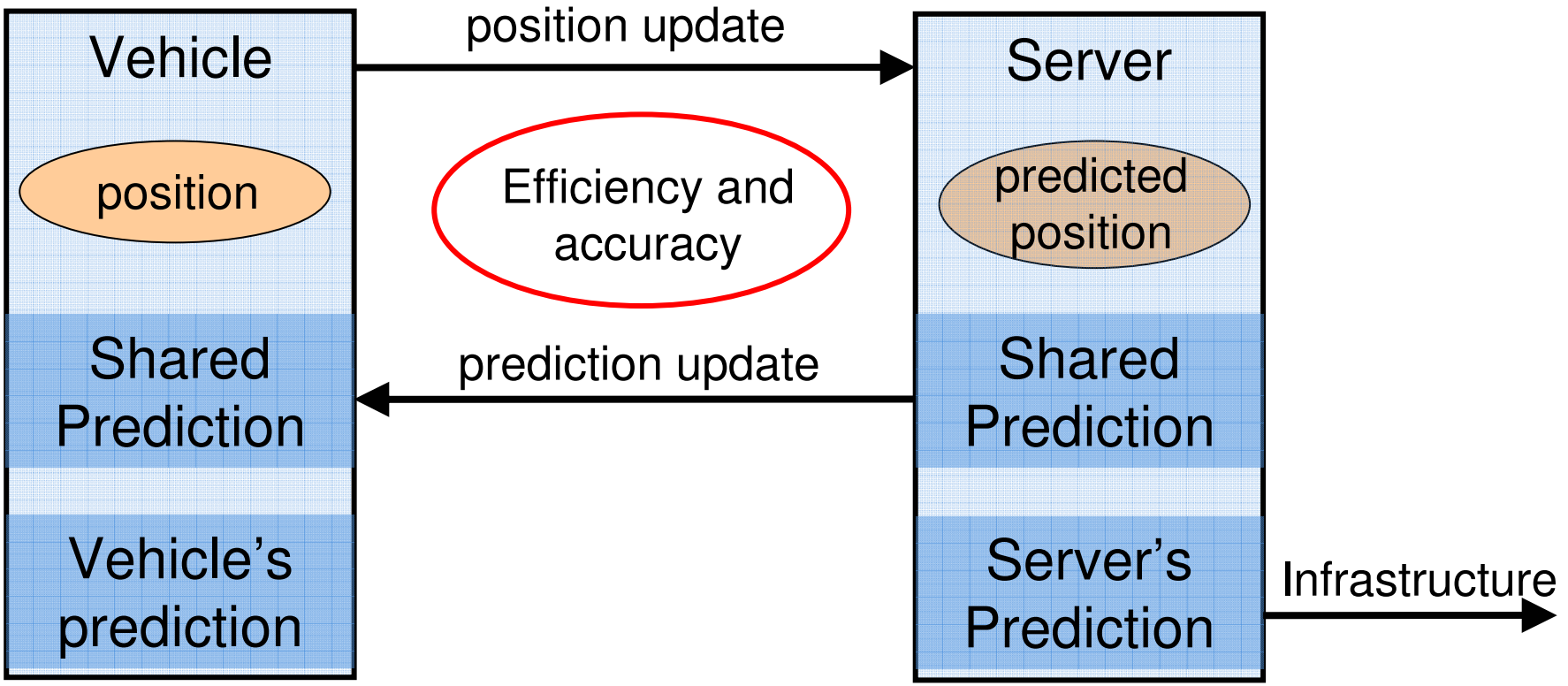
Tracking and Prediction Problem

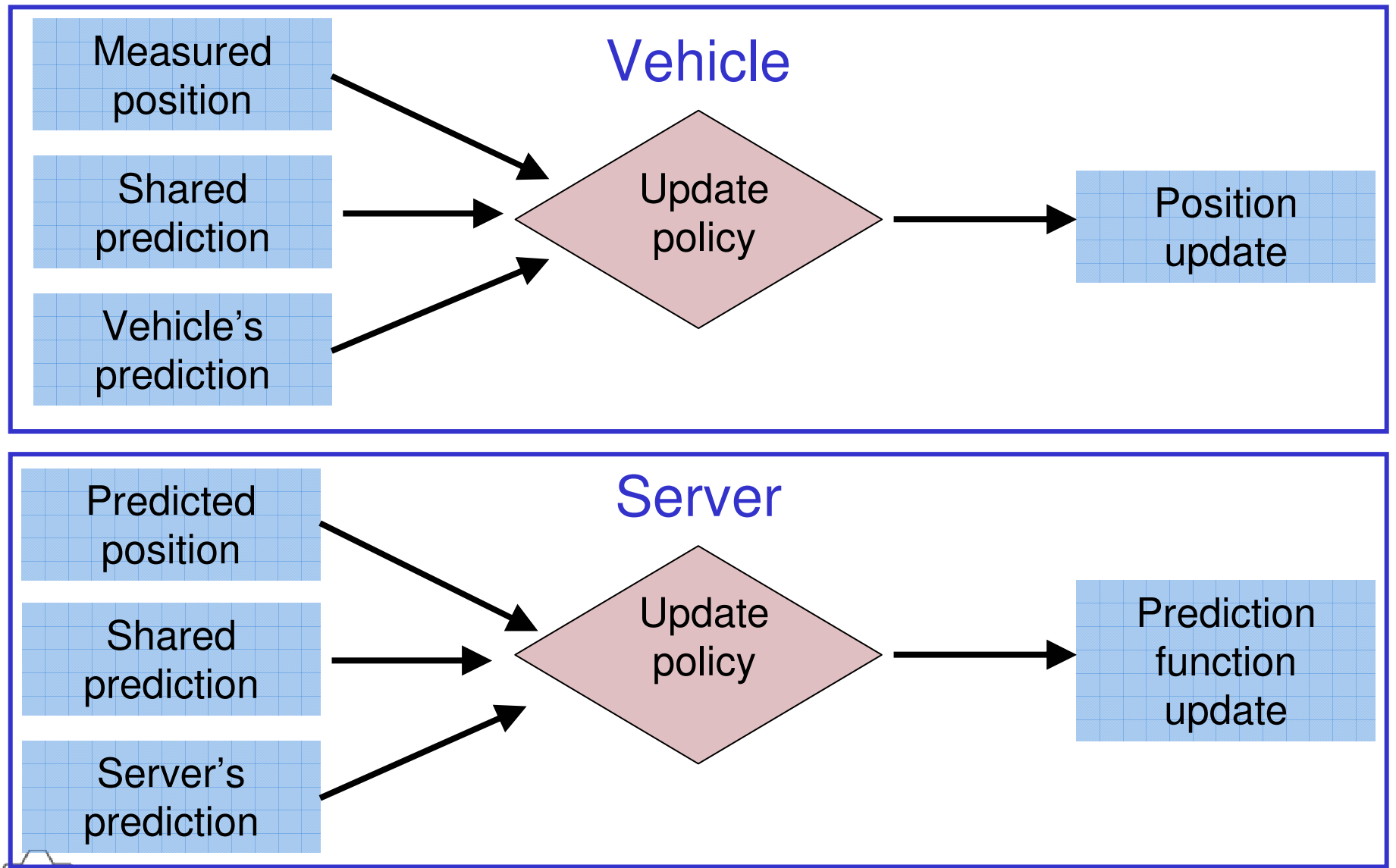
- Goal: maintain accurate positions and predictions at minimal costs.



Problems and Challenges

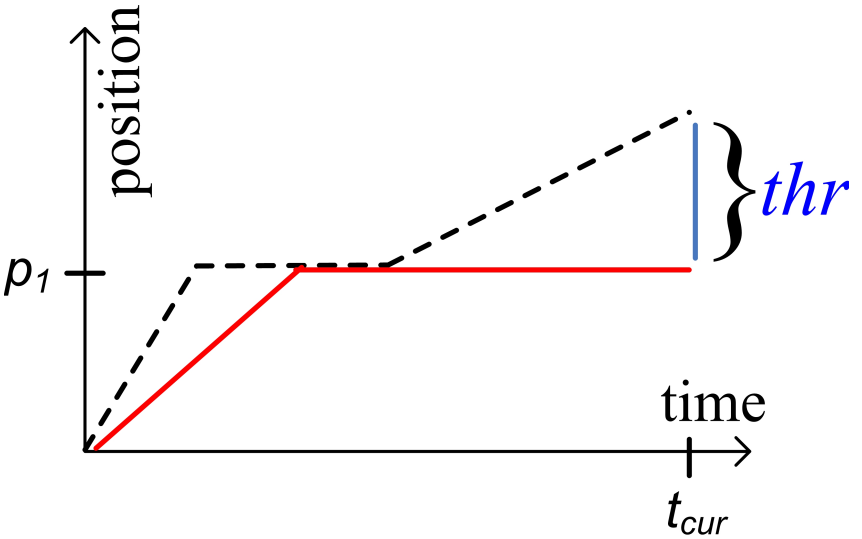
- Accurate prediction of the current and future vehicle's positions.
- Efficient communication in-between the server and the vehicle.
- Analysis of historical trajectories of the vehicles.
  - *Similarity* of vehicle trajectories.
  - Derivation of *travel patterns*.
  - *Application* of travel patterns in tracking and prediction algorithms.

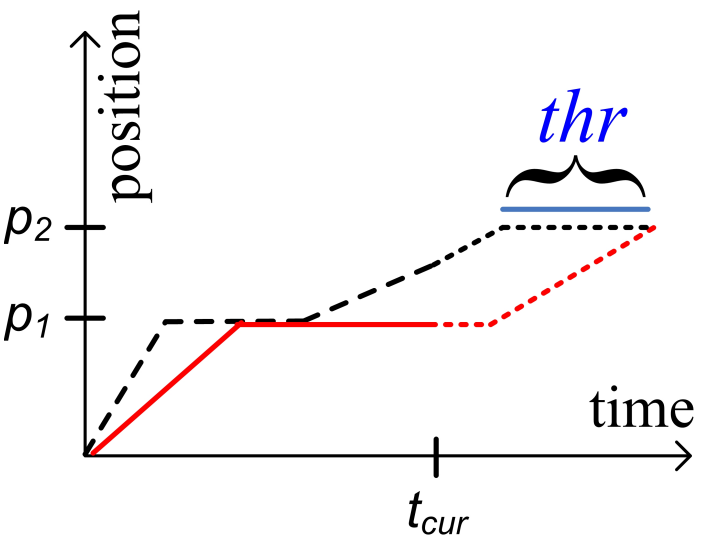
The Tracking Problem



Update Policies

- Position-based tracking
  - Update when the GPS *position* deviates by threshold from the server's predicted position.
  - Provides position accuracy guarantees.
- Time-based tracking
  - Update when the vehicle's *predicted arrival time* deviates by threshold from the server's predicted arrival time.
  - Can be *more efficient* than position-based tracking, but provides *poor position accuracy guarantees*.





Prediction Updates

- Always update when the server's prediction changes.

  Problem: possibly too frequent updates from the server to the vehicle.

- Update only when the server's threshold is reached.

  Problem: possibly too frequent updates from the vehicle to the server.

- Update either when:
  - the server's threshold has been reached, or
  - the update would reduce further communication costs.

  Challenge: how to estimate the numbers of updates?

Prediction Updates

- The Cost Function estimates further communication costs of the journey.
  - Actual costs:

$$cost_{journey} = update\_number \times cost_{up}$$

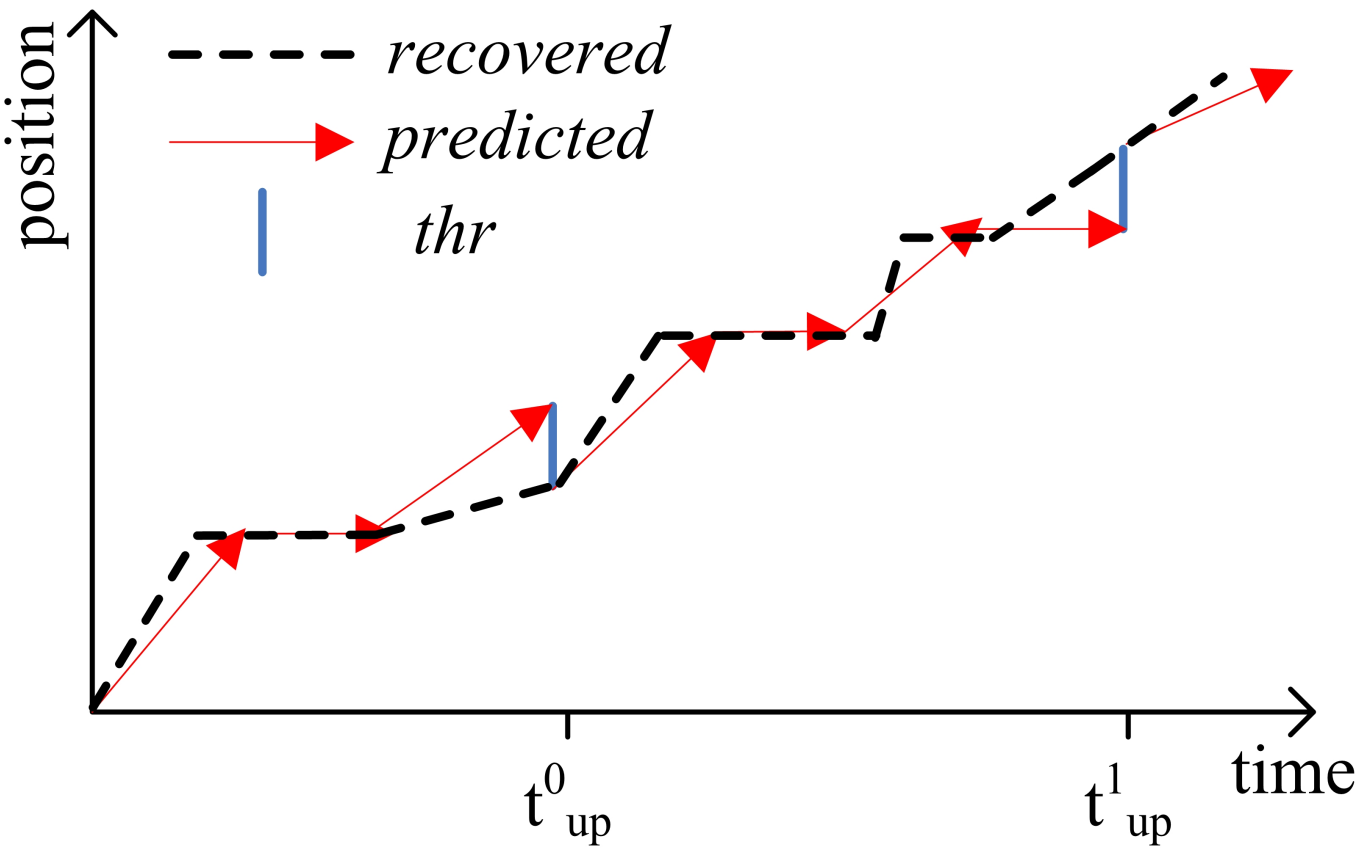
  - Estimated costs:

$$cost_{journey} = \sum_{i} P(update\_number = i) \times i \times cost_{up}$$

  - The costs depend on:
    - The deviation of the old and the new prediction functions.
    - The reliability of the server's prediction.
    - The accuracy thresholds.
    - The cost function.

Historical Trajectories

- Recover vehicle's trajectory from the tracking data.



The Cost Function (Cont.)

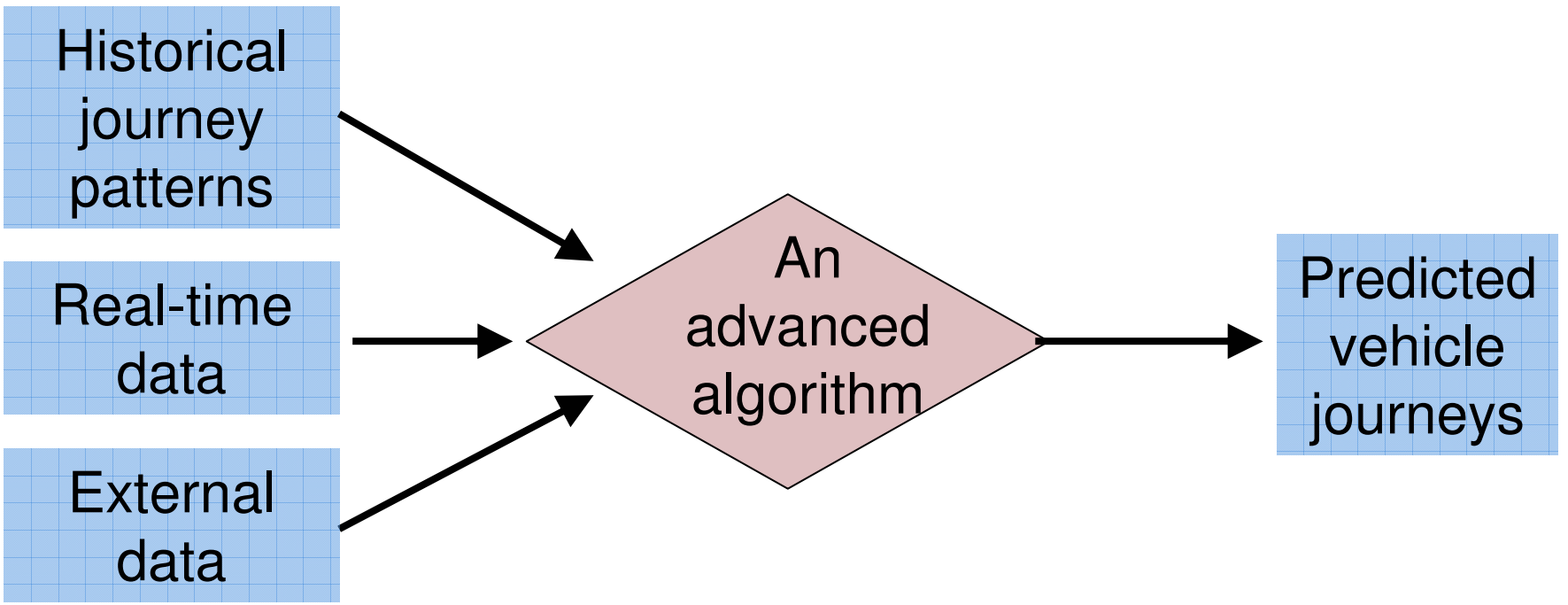
- The cost function depends on:
  - The deviation of the old and the new prediction functions.
  - The reliability of the server's prediction.
  - The accuracy thresholds.
  - The cost function itself.

Tracking Algorithms: Challenges

- Requirements
  - Maintain accuracy guarantees.
  - Minimize the status update costs.

- Challenges
  - The effects of inaccurate predictions have to be minimized.
  - The estimation of prediction uncertainties may help evaluate prediction algorithms and control tracking parameters.
  - System errors, communication delays, and measurement inaccuracies must be taken into account.

Prediction Algorithms

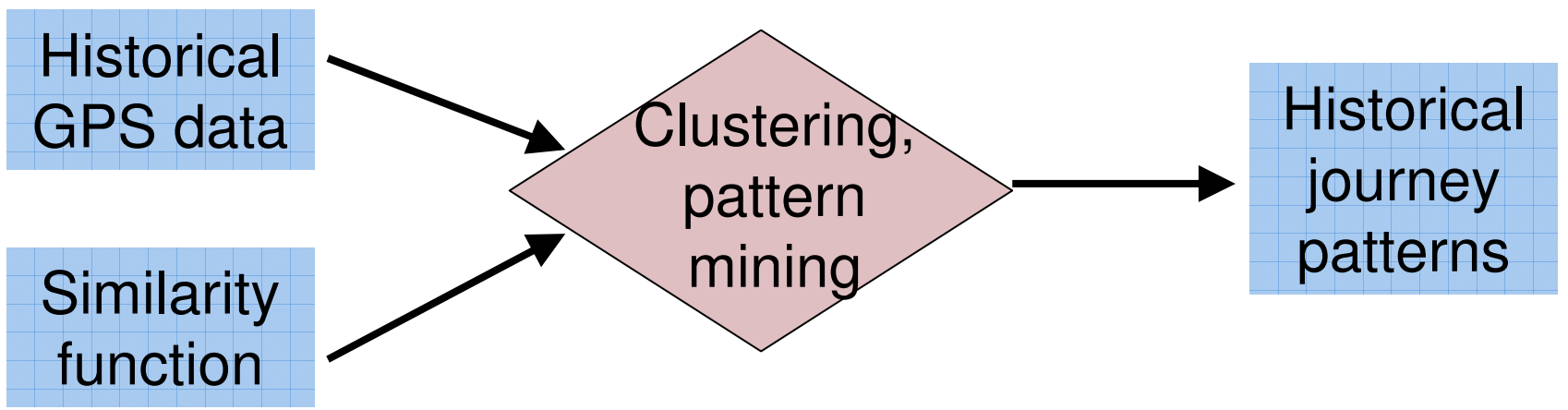


Prediction Algorithms: Challenges

- Requirements
  - Provide *accurate* predictions.
  - Perform *efficient* real-time computations.

- Challenges
  - Identification of correspondences between the *influencing factors*.
  - Efficient utilization of *historical data*.
  - Matching of an ongoing journey against historical journeys.
  - Infrequent real-time position updates.

Statistical Analysis



Similarity Function

- Requirements
  - Enable matching of *sub-journeys*.
  - Satisfy the *metric* properties.
  - Efficient with large amounts of data.

- Challenges
  - Tracking data is “dirty” and sparse.
  - The delays have to be identified “locally”.
  - Correspondences between influencing factors are unknown and have to be discovered.
  - Classify journeys in an intuitive manner.

Historical Pattern Analysis

- Requirements and challenges:
  - Represent the actual distributions of the trajectories and the patterns.
  - Updated by the system as more data becomes available.
  - Efficiently utilize the spatial and temporal restrictions.

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Conclusion

- Efficient tracking: minimal costs, accuracy guarantees, dependency on prediction algorithms.
- Accurate prediction: external factors are difficult to foresee.
- Historical data analysis: matching of sub-journeys, incomplete tracking data, efficiency.

Challenging!

Acknowledgements

- Nordjyllands Trafikselkab (NT)
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  (www.cs.aau.dk/TransDB)

☺ Thank you! ☺

Questions?

Suggestions?

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