HTTP: A New Framework for Bus Travel Time Prediction Based on Historical Trajectories

Wang-Chien Lee[1], Weiping Si[1], *Ling-Jyh Chen*[2], Meng Chang Chen[2]

[1] The Pennsylvania State University, PA, USA
[2] Academia Sinica, Taiwan

2012 ACM SIGSPATIAL GIS
Nov. 6-9, 2012 - Redondo Beach, CA, USA

Observation

- Public transportation has become increasingly important.
- Customer Satisfactory is a high priority to various public transportation services.
- Many intelligent transportation services have been deployed in major cities world-wide, e.g., real-time bus information system.

Taipei e-Bus System

- Deployed since 2004
- 4,000+ buses, 300+ routes, 15 agencies
- Each bus sends its GPS location to information center every minute
- MANY applications…

Taipei e-Bus System (cont'd)

Taipei e-Bus System (cont'd)

- It looks perfect, but…
  - MANY people complain the bus arrival time prediction is inaccurate.
  - Government says sorry many times, but has no good solutions yet :<
  - The prediction problem is very challenging, because there are many affecting factors, (e.g., *traffic lights, congestion, accidents, and MRT stations*) and the prediction error is accumulated for future bus stops.

Our Contribution

- We perform a detailed analysis to investigate the correlation between bus travel times in route segments and their temporal features based on historical data.
- We propose a new system framework, called HTTP, for travel time prediction of an on-going bus journey.
- We evaluate the proposed approach, in terms of prediction accuracy, using real bus dataset.

Related Work

- Travel time prediction [11, 22, 23, 34]
  - Mostly AI-based approaches that are computational expensive
  - Accurate for short-term prediction, but not for long-trips
- Trajectory similarity [2, 4, 7, 9, 12, 25, 26, 30]
  - Exploit conventional similarity measures for time series
  - Highly sensitive to errors and outliers
- Trajectory patterns [5, 13, 28, 33]
  - Classified trajectories in two aspects: trends and periodicity
  - Used to predict traffic condition of the same segment

Problem Formulation

- Bus route:

  $R = \langle P_0, P_1, \ldots, P_n \rangle = \langle S_0, S_1, \ldots, S_{n-1} \rangle$

  where $\boldsymbol{P_i}$ is the i-th stop in a route, and $\boldsymbol{S_i}$ is the route segment between $\boldsymbol{P_i}$ and $\boldsymbol{P_{i+1}}$

- Bus trajectory:

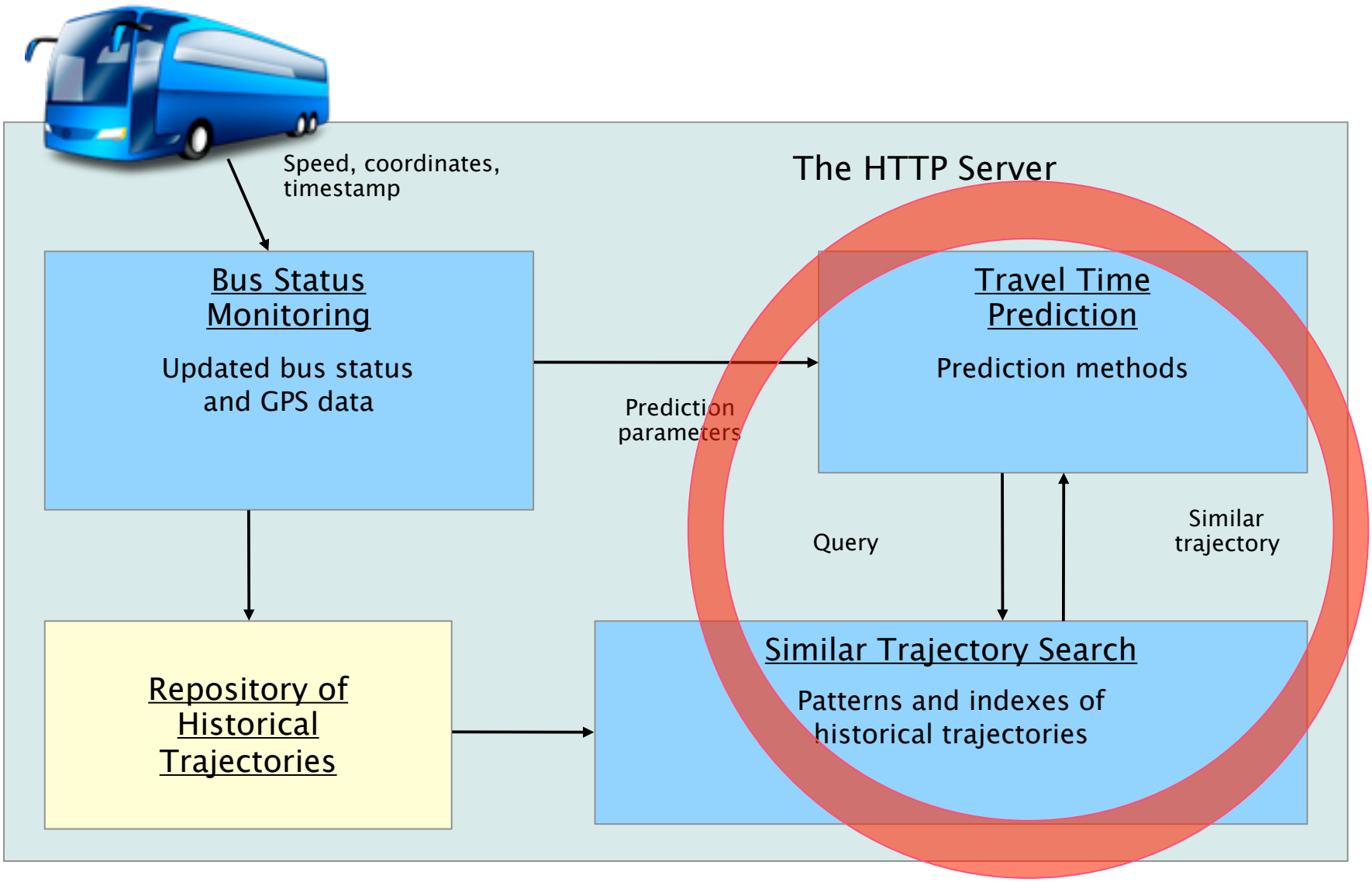
  $T = \langle\langle P_1, t_1\rangle, \langle P_2, t_2\rangle, \ldots, \langle P_n, t_n\rangle\rangle$

  $= \langle \Delta t_1, \Delta t_2, \ldots, \Delta t_{n-1} \rangle$

  where $\Delta t_i = t_{i+1} - t_i$ is the travel time on $\boldsymbol{S_i}$

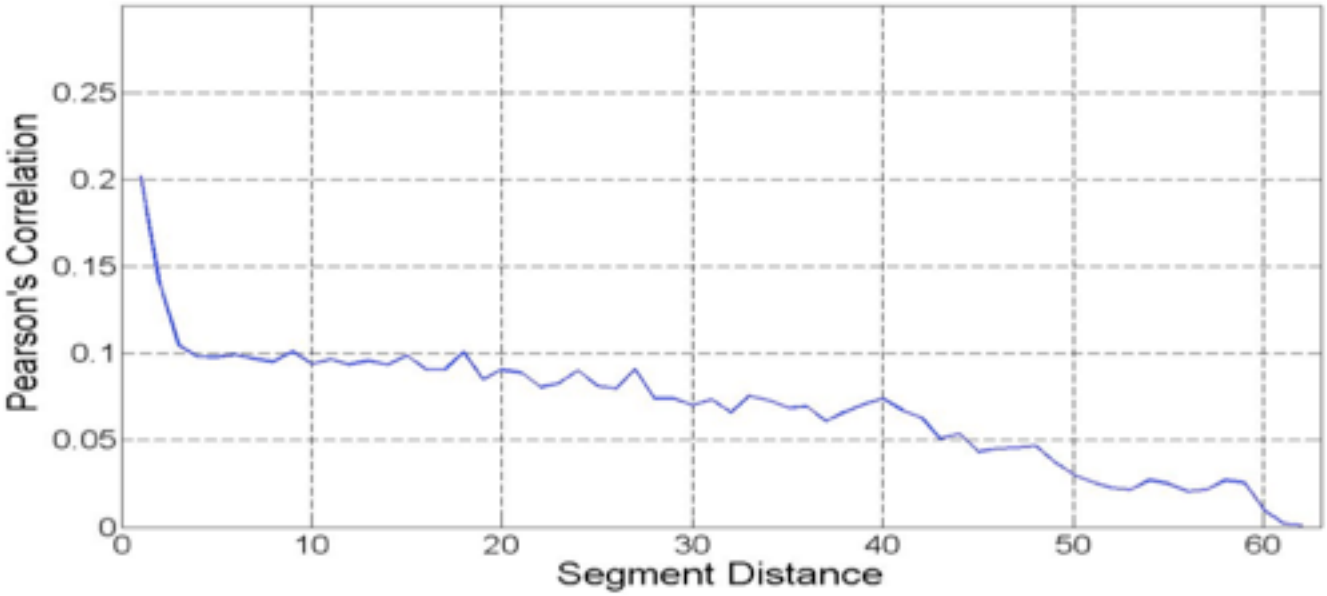
- Given $T' = \langle \Delta t'_1, \Delta t'_2, \ldots, \Delta t'_i \rangle$ and $R = \langle P_0, P_1, \ldots, P_n \rangle$, the travel time prediction problem is to predict $\langle \Delta t'_{i+1}, \Delta t'_{i+2}, \ldots, \Delta t'_{n-1} \rangle$ in this trajectory

HTTP: System Overview

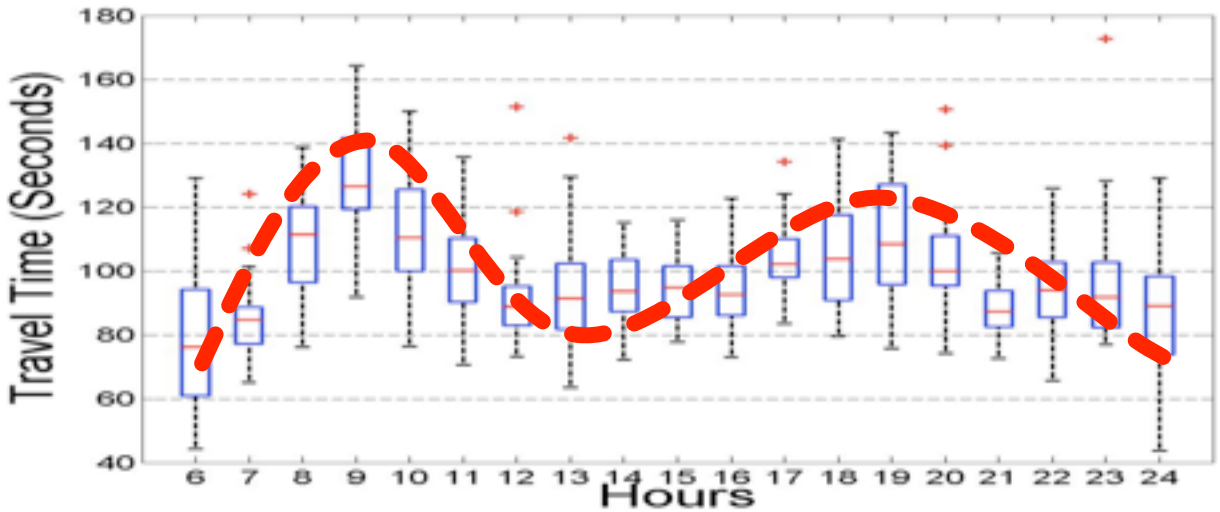


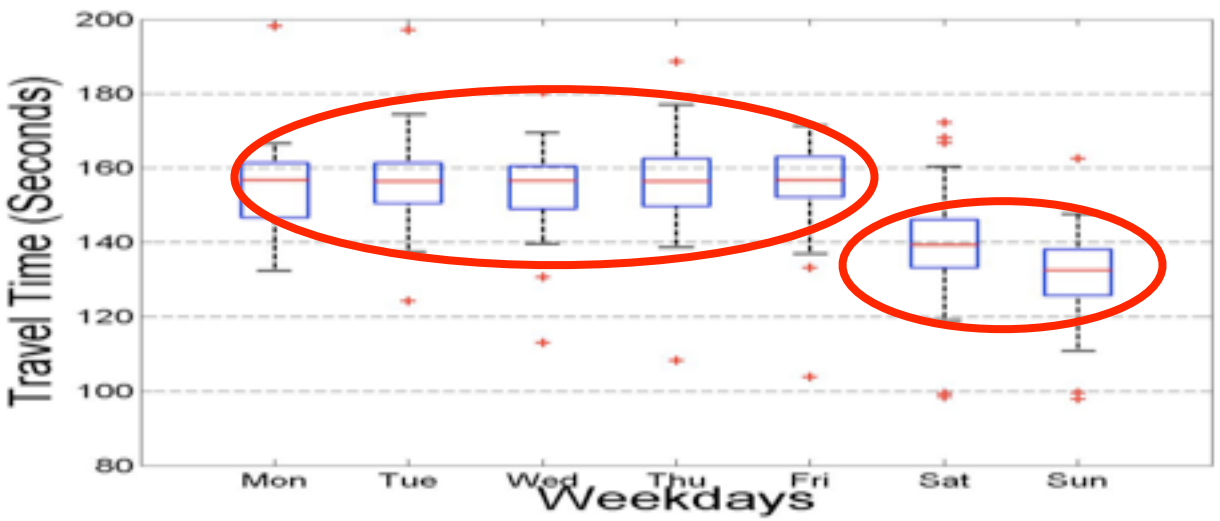
Data Analysis

- Dataset
  - One 47.4km long bus route in Taipei
  - 24,985 trajectories from 2010/3 to 2011/3
- *The closer segments, the higher correlation!*



Data Analysis (cont'd)





Method 1: Passed Segments Scheme

- We extend the conventional notion of trajectory similarity by *considering two trajectory similar when the difference for a segment is less than the threshold specified*.
- To avoid *exhaustive* similarity comparison of all the trajectories in the repository, we partition the travel times for each segment into groups (using K-Means/V-Clustering).
- To *efficiently* identify similar trajectories using the travel times on passed segments of an on-going bus journey, we adopt the *segment filtering* approach to select similar trajectories.

Method 2: Temporal Features Scheme

- We consider two temporal features, "hours of a day" and "days of a week", in historical dataset.

- We adopt the K-Modes algorithm to partition all the trajectories passing a segment into *K* clusters using feature vectors and use the best matched cluster for prediction.

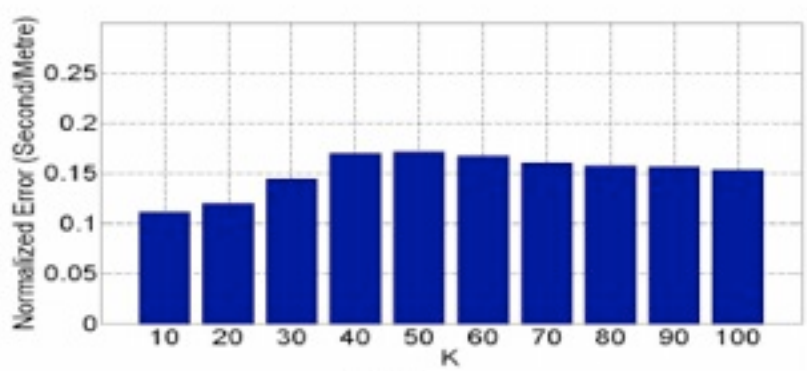
Method 3: Hybrid Scheme

- The PS and TF schemes are both based on historical trajectories, they can be easily combined into hybrid schemes.
  - Hybrid Passed segments/Temporal features (HPT)
    - Find a set of similar trajectories in terms of travel times of the passed segments and then filter using the temporal features
  - Hybrid Temporal features/Passed segments (HTP)
    - First apply TF and then PS

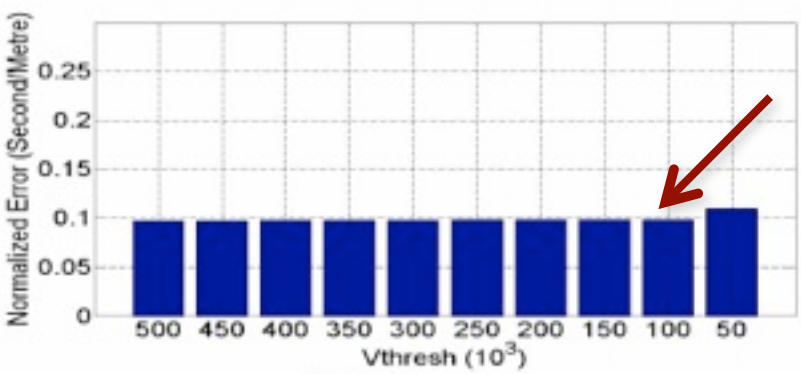
Evaluation

- Bus dataset from 2010/3 to 2011/2 as the historical dataset
- 508 trajectories in the first week of 2011/3 as the testing data
- Evaluate six schemes
  - Passed segments (PS)
  - Temporal features (TF)
  - Hybrid passed segments/temporal features (HPT)
  - Hybrid temporal features/passed segments (HTP)
  - TransDB [22]
  - Average prediction (AP)

Evaluation: Tuning the PS scheme



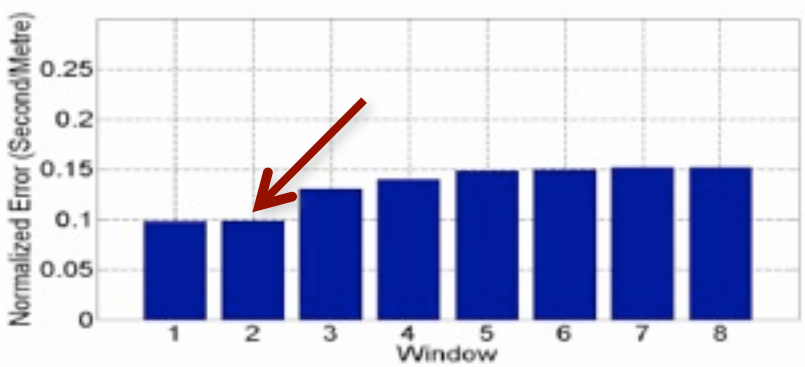
(a) Kmeans



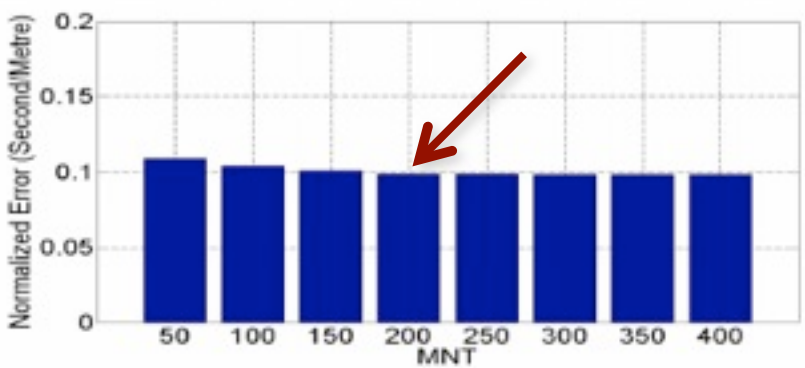
(b) VClustering

- PS w/ V-Clustering outperforms PS w/ K-Means.
- We suggest Vthresh = 100K, which is the maximum difference of weighted average variance allowed between two iterations.

Evaluation: Tuning the PS scheme (cont'd)



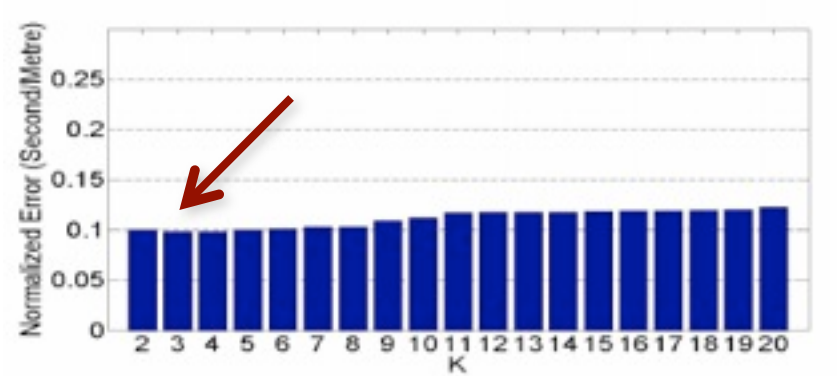
(a) Window size



(b) MNT

- *Window of segment filter (window)* is the number of the passed segments to look back, and we suggest window = 2.
- *Minimal number of trajectory (MNT)* is to ensure a minimum number of trajectories remained in the dataset, and we suggest MNT=200.

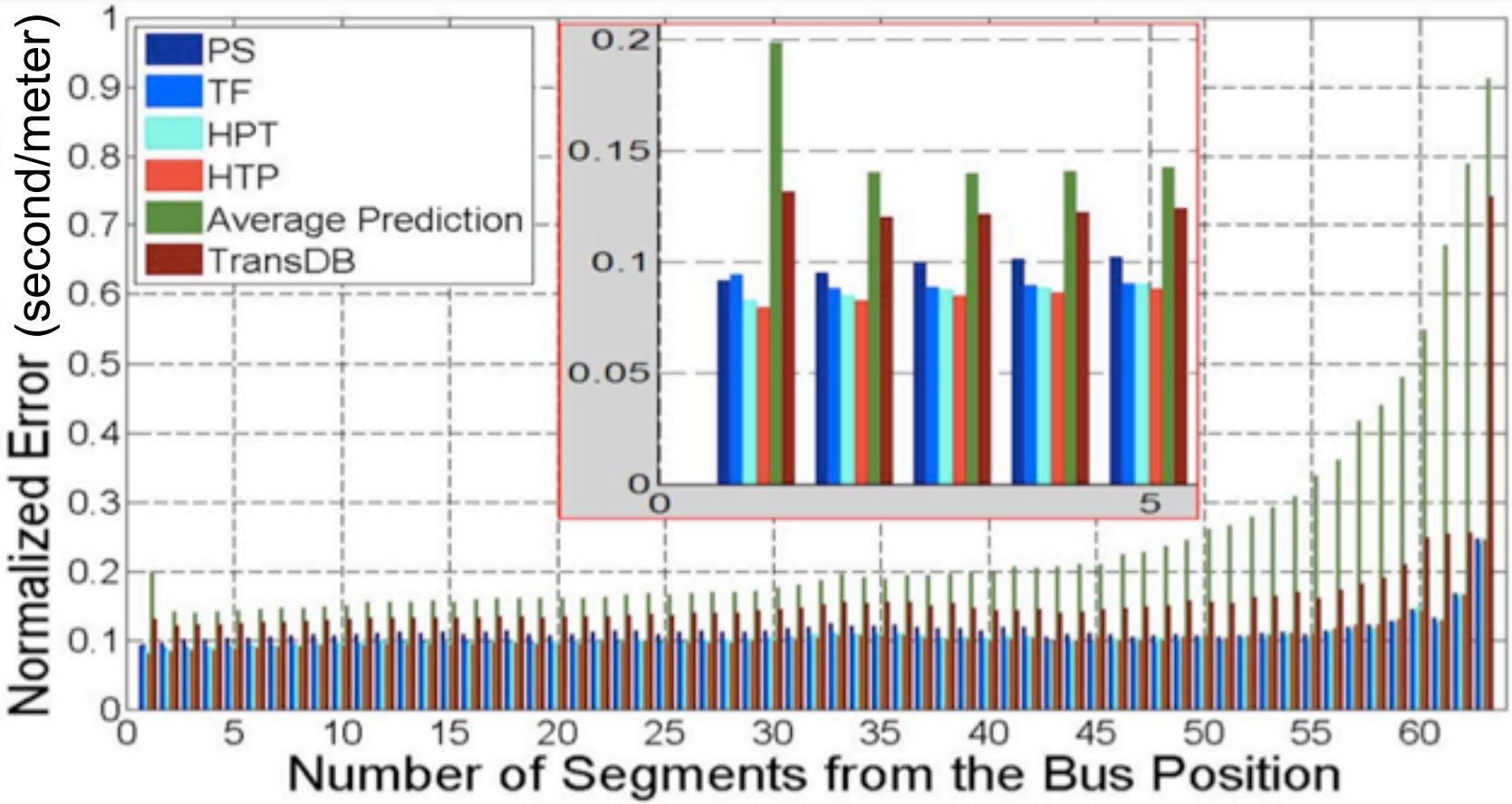
Evaluation: Tuning the TF scheme



- We suggest K=3 for the K-Modes scheme used in the TF scheme.

Evaluation: Comparison

The prediction error increases as the segment distance increases.



Normalized error: HPT/HTP < PS/TF < AVG/TransDB

HTP is slightly better than HPT -> Temporal Feature does matter!

Conclusion & Future Work

- Propose a prediction framework and develop two basic travel time prediction schemes
- Use a real dataset to evaluate the effectiveness of the proposed prediction schemes and produce good results
- Plan to explore more features and patterns from the historical trajectory data for the future work

Thank for your attention!