Aftab Ahmed Chandio, Nikos Tziritas, Fan Zhang, Ling Yin, Cheng-Zhong Xu, 2016. Towards adaptable and tunable cloud-based map-matching strategy for GPS trajectories. *Frontiers of Information Technology & Electronic Engineering*, **17**(12):1305-1319.
http://dx.doi.org/10.1631/FITEE.1600027

Towards adaptable and tunable cloud-based map-matching strategy for GPS trajectories

Key words: Map-matching, GPS trajectories, Tuning-based, Cloud computing, Bulk synchronous parallel BSP

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Motivation/Main ideas

Motivation

- Due to the rapid increase of data volume within the transportation domain, cloud environment is of paramount importance for storing, accessing, handling, and processing such huge amounts of data.
- A large part of data within the transportation domain is produced in the form of global positioning system (GPS) data.
- Due to the high computation cost incurred by SPQs, the current map-matching strategies are not suitable for real-time processing.

Main ideas

- To propose a real-time map-matching (RT-MM), a fully adaptive map-matching strategy based on cloud,
- To address the key challenge of SPQs in a map-matching process for real-time GPS trajectories.
- The evaluation of the approach against state-of-the-art approaches is performed through simulations based on both synthetic and real-world datasets.

Method (I)

We address the problem of map-matching strategies. Particularly, map-matching strategies follow three major steps, shown in Fig. 1.

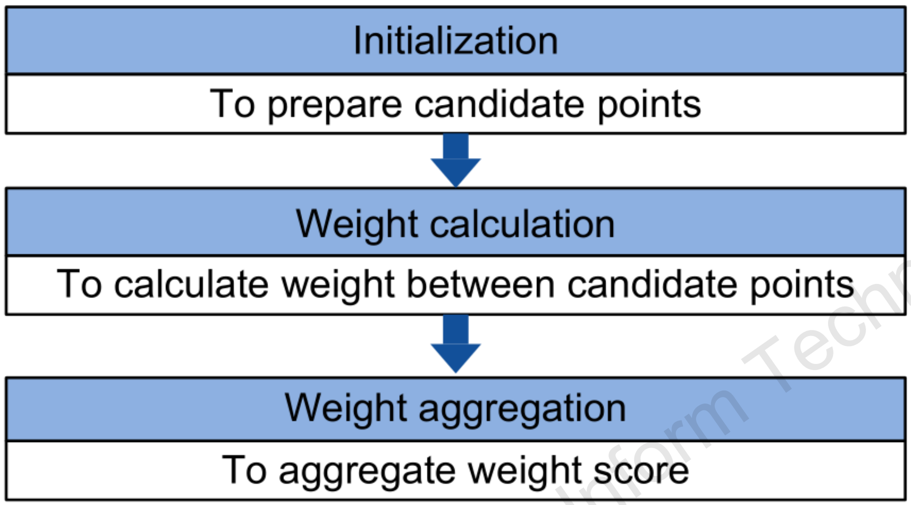


Fig. 1 Basic steps in a map-matching process

A complete systematic model of our proposed technique consists of two main steps: off-line and online efforts.
The architecture of the system is shown in Fig. 4.

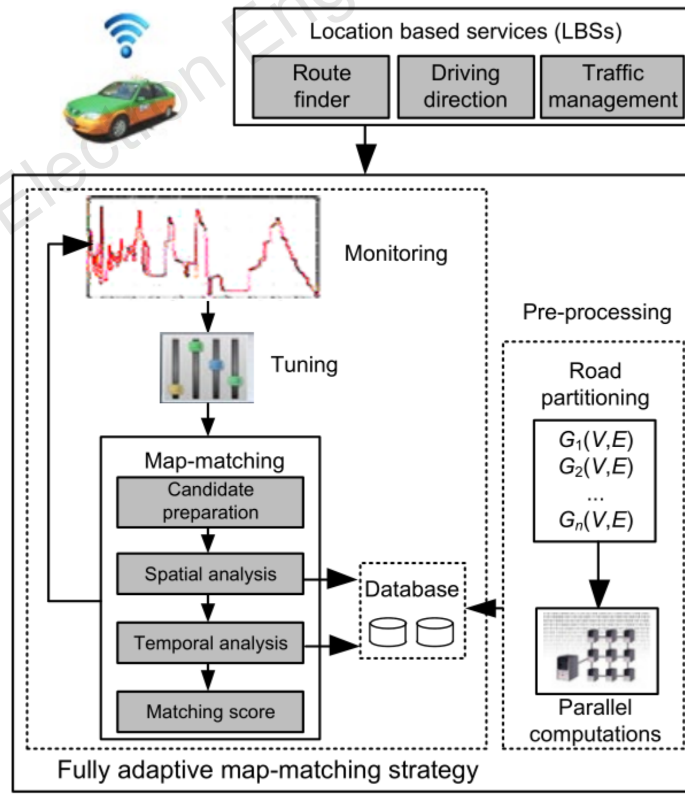


Fig. 4 An overview of the proposed system

Method (II)

We choose the BSP tool to perform the shortest path computations.

BSP algorithm will generate a series of supersteps,

Each superstep executes a user-defined function in parallel asynchronously.

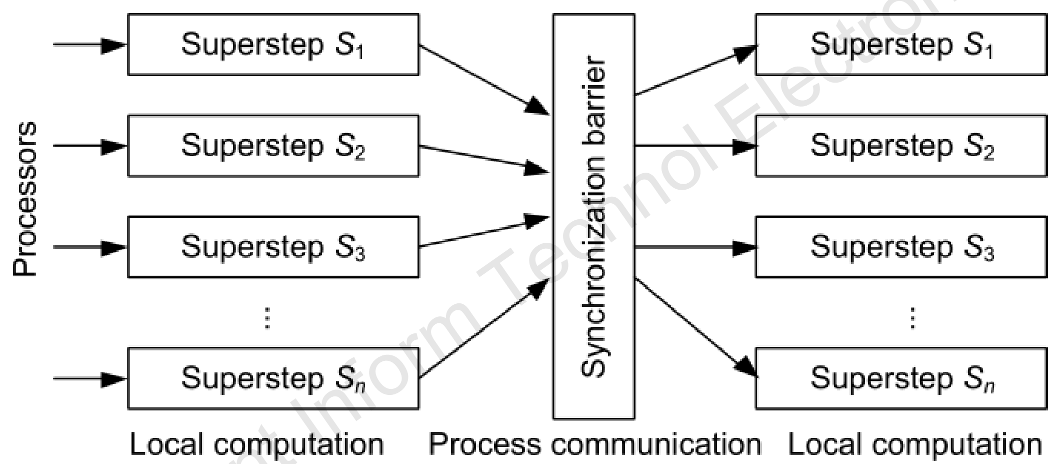


Fig. 6 A snapshot of bulk synchronous parallel (BSP) processing

We modified the SSSP function following the BSP parallel paradigm.

It takes a road network graph as input.

Method (III)

We propose a novel approach of applying an adaptive strategy to adjusts the sampling rate of GPS data and fine-tunes the map-matching parameters.

Fig. 7 shows three sliding windows to maintain trajectory continuity. The second and third sliding windows follow the most recent results (i.e., last mapped GPS point) of the previous sliding window.

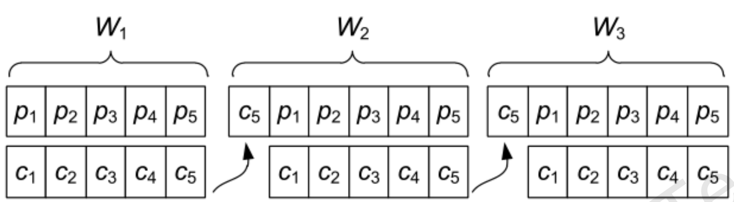


Fig. 7 An example of the proposed window-based map-matching scheme for real-time trajectory (W=5), where p_1, p_2, …, p_5 denote the GPS sampling points and c_1, c_2, …, c_5 denote the corresponding correct candidate points

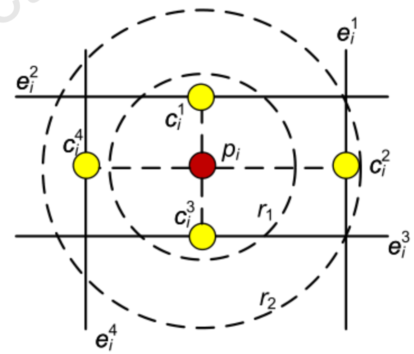


Fig. 3 The interior setting for considering candidate points (CPs) for a sampoing point

The tuning strategy decides the interior settings based on the locality of the road network.

Fig. 3 shows a snapshot of two fixed ECR (i.e., r_1 is small and r_2 is large). As shown, for point pi, two CPs can be considered if ECR is equal to r_1 (small), otherwise, four CPs are considered if ECR is equal to r_2 (large).

Major results (I)

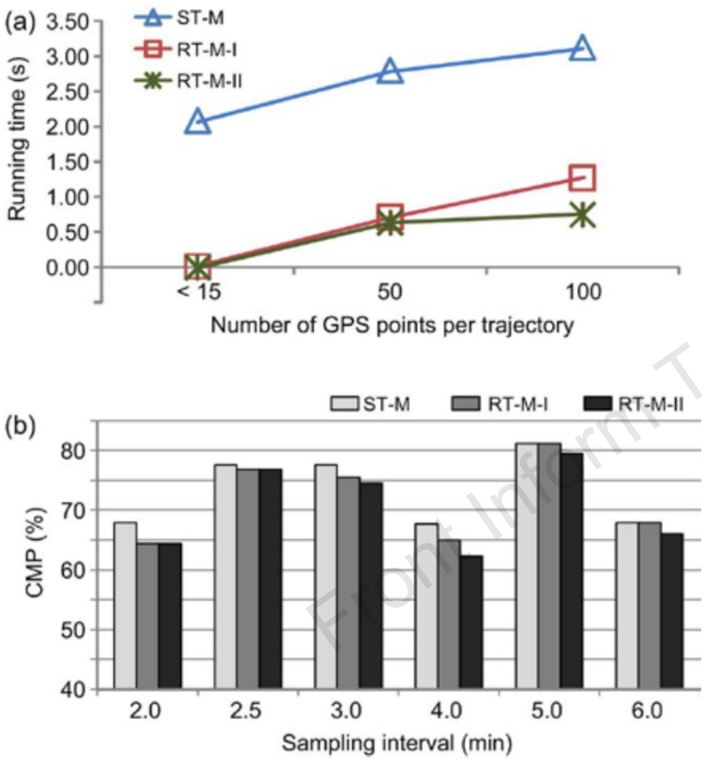


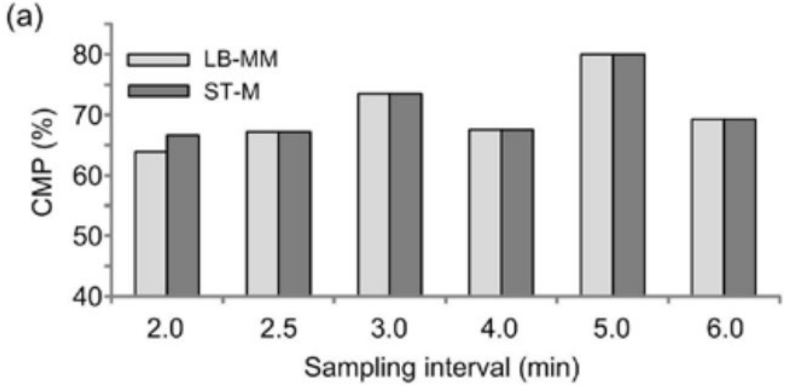
Fig. 8 The running time with different numbers of GPS points per trajectories (a) and the accuracy with different sampling intervals for the synthetic dataset (b)

We analyze the proposed RT-M strategy against ST-M regarding running time and accuracy.

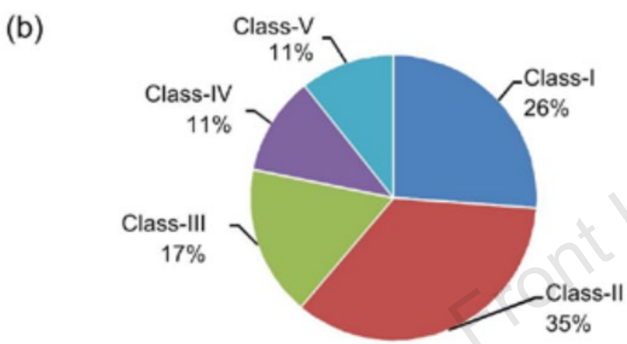
The results shown in Fig 8a reveal that our proposed strategies took much less computation time as compared to ST-M algorithm.

Fig. 8b shows the comparison of the average CMP of synthetic trajectories when varying the sampling-rate from 2 to 6 min per trajectory. Our proposed strategies produced almost the same results as that of ST-M.

Major results (II)



We also evaluated the proposed adaptive strategy in terms of CMP and the distributions of GPS sampling points.



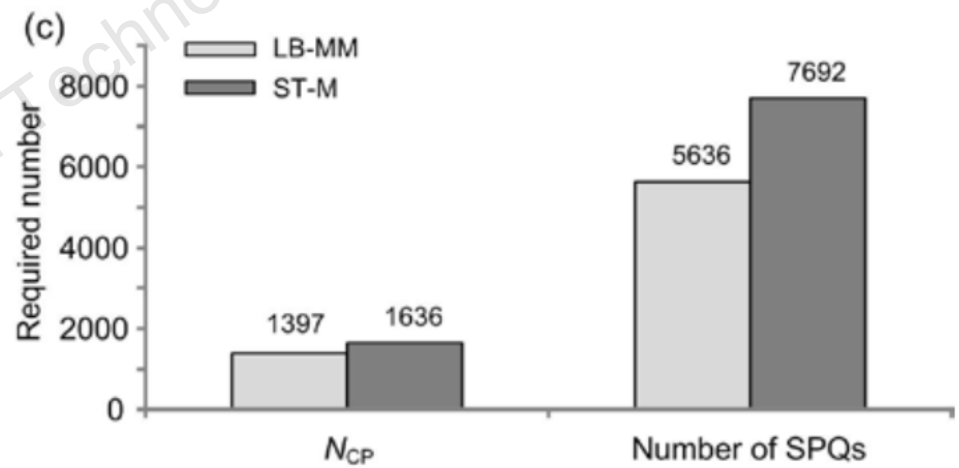


Fig. 10 Comparison evaluation of locality of the road network: (a) CMP with respect to different GPS sampling rates; (b) distribution of GPS sampling points in each class; (c) number of CPs and SPQs required

Major results (III)

We examined the distributions of GPS sampling points in each class when processing the full-day real-world trajectory (Table 3).

Result clearly discloses that the classes based on the locality of the road network are adaptively selected by the proposed strategy for each GPS sampling point of the trajectory.

Table 3 Distributions of GPS sample data in each class for matching a full-day real-world trajectory

Class	Number of GPS sampling points			Percentage
	Inside-city	High-way	Total	
Class-I	223	414	637	42.10%
Class-II	255	315	570	37.67%
Class-III	99	113	212	14.01%
Class-IV	24	23	47	3.11%
Class-V	15	32	47	3.11%
Total	616	897	1513	100.00%

Major results (IV)

Furthermore, we evaluated the performance of the adaptive strategy RT-M-II against the strategy RT-M-I with the number of CPs equal to 5 and ECR equal to 100 m..

The results are shown in Table 4, which indicates that RT-M-II outperformed RT-M-I. Specifically, the adaptive strategy significantly reduced the number of SPQs and CPs required.

Table 4 Performance comparisons between the adaptive strategy RT-M-II against the static strategy RT-M-I for full-day real-world trajectory map-matching

GPS point type	N_{CP}		N_{SPQ}		N_{CLF}	
	I	II	I	II	I	II
In-city	3145	1942	22 414	12 255	385	224
High-way	3350	2704	19 237	11 726	295	346
Total	6495	4646	41 651	23 981	680	570
Ratio	1.398		1.737		1.193	

N_{CP}: number of CPs; N_{SPQ}: number of SPQs; N_{CLF}: number of CPs less than the fixed value of the CP parameter. I: RT-M-I strategy; II: RT-M-II strategy

Conclusions

- It is evident that location-based services (LBSs) become more and more data hungry.
- We proposed a fully adaptive map-matching strategy for real-time GPS trajectories based on cloud environment.
  - adaptively fine-tunes the interior and exterior parameters of the map-matching process,
  - the shortest path distance and the speed constraint of road segments are pre-computed by following the bulk synchronous parallel (BSP) paradigm,
- Results revealed that, by assigning an appropriate class of the locality of a road network for mapping each GPS sampling point, the total number of CPs and SPQs can be significantly reduced, thus considerably decreasing the execution time.