MITSUBISHI-A project

Title:
Construction of metrics for map matching between travel trajectories and map graphs

Industrial Partner:
MITSUBISHI Electric Corp., Advanced Technology R&D Center.

Mitsubishi Electric, founded in 1921, is an electronical and electric equipment manufacturer, developing products and solutions in a wide range of fields, including home appliances, industrial equipment, and space technologies. Advanced Technology R&D Center was established to support the business of Mitsubishi Electric Group through the development of a broad scope of projects covering both basic and new advanced technologies. The main research themes include power electronics, mechatronics, satellite communications, next-generation key devices, system solutions for electric power, transportation, factory automation, and automobiles.

Industry Mentor:
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Introduction:
Recently, maps utilized for navigation systems have become more precise because of developments of ADAS (Advanced Driver-Assistance Systems) and ADS (Automated Driving Systems.) Previsouly, maps for navigation systems were stored in roadway units. Currently, maps for ADAS/ADS, called HD maps (High-Definition maps), are stored in lane units, and the network structure of maps has become huge and very complicated (cf. Figure 1.)

If we would like to specify our position in an HD map, we need to localize our position with less than several meter accuracies. However, GPS (Global Positioning System) may have an error of several meters because of multipath errors from buildings and so on, and it is hard to localize our position in HD map in some scenes by GPS. For this reason, we need to use an expensive high-precision positioning system or inertial navigation system to localize our position.

On the other hand, map-matching algorithms achieve such localizations in HD maps in a much less expensive way. Map matching enables us to find the correct travel route from an HD map even if the GPS has errors that are greater than the precision of an HD map. Such matching is obtained by using optimization techniques for consistency between travel routes and candidate routes. The formulations use knowledge of mathematics like geometry or probability theory.

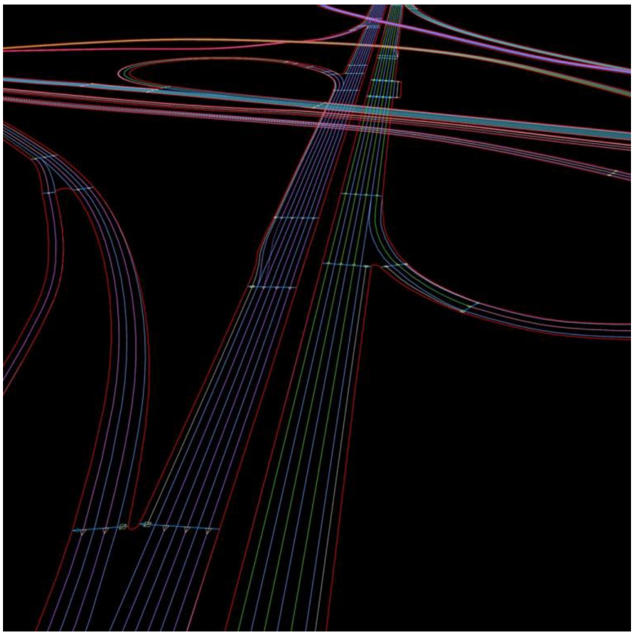

Figure 1 An image of a High Definition map (from https://www.here.com/learn/blog/here-introduces-hd-live-map-to-show-the-path-to-highly-automated-driving)

Technical Background:

Map matching in this project is defined as finding the correct travel route from map and trajectory data (cf. Figure 2). It means extracting connected sub(di)graphs as the candidates from the map represented as (di)graphs and selecting only one route by using time series data like position, direction, and speed.

To build a map-matching algorithm for several scenes, we need to treat not each point of the trajectory but the trajectory itself. If we can get enough high-precision GPS data for map matching, map matching can be proceeded by just using the nearest neighbor search between each point of the trajectory and map. Otherwise, such map-matching algorithms cause failures to find the correct travel route. For this reason, previous works consider some kind of loss functions or distances between the map and trajectory itself and get the correct travel route by minimizing the loss functions.

The potential for developments in map-matching algorithms directly corresponds to the difficulty in the modification of loss functions. For the simplest case of map matching, it treats only undirected graphs as maps and 2-dimensional position series as trajectories. If we would like to treat additional information like one-way traffic, azimuth, or speed, we need to modify the definition of the loss function to include this information. One of our aims is to define a new loss function that can be modified easily based on mathematics.

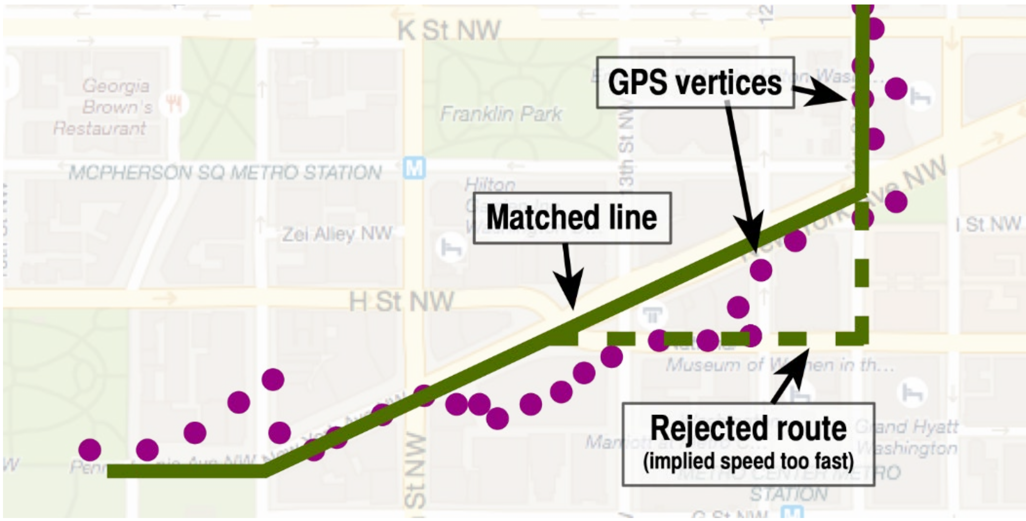

Figure 2 Map matching overview (from GitHub: amillb/pgMapMatch)

Expectations:

In this project, we formulate a new map-matching algorithm based on an analysis of previous studies about hidden Markov models and so on. In a project held last year, new map-matching algorithms were developed based on physics or optimal transport. In this year's project, it is expected to expand these methods to additional data and scenes or develop new methods that differ from these methods.

As the result, it is expected that students perform simulations and compare the results with previous studies, including quantitative evaluations of the processing time and precision.

Special Requirements:

We assume basic knowledge of elementary geometry, probability, statistics, and graph theory in treating geospatial information. Additionally, it is useful (but not required) to have experience with graph theory (like Dijkstra's algorithm), Bayesian statistics (like the Kalman filter), optimization theory, or optimal transport (like the Wasserstein distance.) In order to do simulations of this problem, students are expected to have some programming experience (especially Python). Moreover, it will be helpful to have some knowledge of nearest neighbor search algorithms (like k-d tree.)

Recommended Reading and References:

This current survey for map-matching algorithms is good for the introduction.

[1] Chao, P., Xu, Y., Hua, W., & Zhou, X. (2020, February). A survey on map-matching algorithms. In *Australasian Database Conference* (pp. 121-133). Springer, Cham.

It is also useful to know traditional and heuristic map matching by

[2] Quddus, M. A., Ochieng, W. Y., & Noland, R. B. (2007). Current map-matching algorithms for transport applications: State-of-the art and future research directions. *Transportation research part c: Emerging technologies*, *15*(5), 312-328.

Some famous algorithms use hidden Markov model. It is introduced by

[3] Newson, Paul, and John Krumm. "Hidden Markov map matching through noise and sparseness." *Proceedings of the 17th ACM SIGSPATIAL international conference on advances in geographic information systems*. 2009,

One of the implementations is open to the public. The article is

[4] Yang, C., & Gidofalvi, G. (2018). Fast map matching, an algorithm integrating hidden Markov model with precomputation. *International Journal of Geographical Information Science*, *32*(3), 547-570,

and the source code is located at “https://github.com/cyang-kth/fmm.”

In other case, particle filter, which is a kind of Bayesian filter, is utilized.

[5] Wang, Xuemei, and Wenbo Ni. "An improved particle filter and its application to an INS/GPS integrated navigation system in a serious noisy scenario." *Measurement Science and Technology* 27.9 (2016): 095005.

Another case defines a kind of scoring function for map-matching.

[6] Sharath, M. N., Nagendra R. Velaga, and Mohammed A. Quddus. "A dynamic two-dimensional (D2D) weight-based map-matching algorithm." *Transportation Research Part C: Emerging Technologies* 98 (2019): 409-432.

The final report of g-RIPS-Sendai 2022 Mitsubishi-A project should be useful.

[7] Akamatsu, T., Gress, G., Huneycutt, K., & Omura, S. (2022). g-RIPS Sendai 2022 Mitsubishi-A group final report.
https://www.racmas.tohoku.ac.jp/g-rips/pdf/MITSUBISHI-A_FinalReport.pdf