MITSUBISHI-A project

Title:
Construction for incomplete map matching based on local and global geometries

Industrial Partner: Advanced Technology R&D Center of MITSUBISHI Electric Corp.
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, or 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, or factory automation and automobiles.

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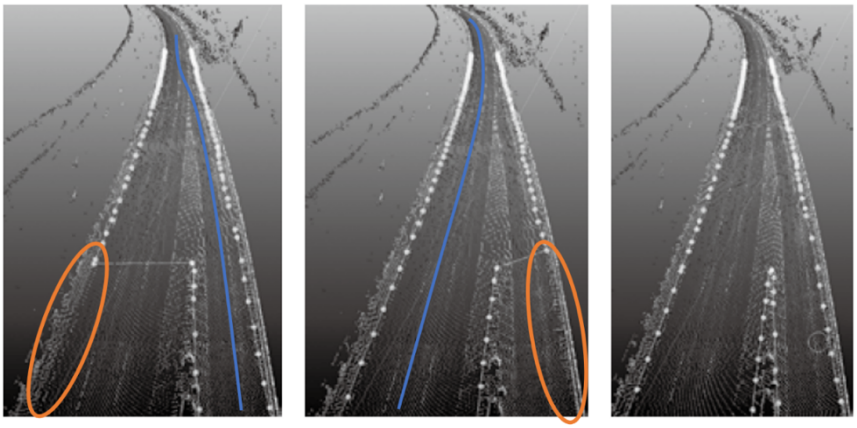
Introduction:

One of the topics of geospatial information processing is matching between incomplete maps to maintain geospatial information. The technology is needed for multiple mapping systems that generate huge and/or precise maps efficiently. In general, maps generated by multiple mapping systems are incomplete because of obstacles that hide several areas. To generate a consistent map from the incomplete maps, suitable matching and integration between incomplete maps should be proceeded. Figure 1 shows an example where circles in (a) and (b) correspond to incomplete information due to the separated traffic lanes (blue lines). In Fig. 1 (c), they have been successfully merged.

One of the examples of such system is the Simultaneous Localization and Mapping (SLAM) system by multiple robots. SLAM is used for activities in spaces whose maps are not given, and it is currently used for cleaning robots and so on. In the case of SLAM (by multiple robots), shapes of the environment are obtained as 3D sampling points (a so-called point cloud). When considering to construct accurate road maps, the point clouds obtained through SLAM are incomplete, which in turn might lead to incomplete road maps. Therefore, matching and integration for incomplete maps are necessary to produce a complete map from SLAM results of multiple robots.

In fact, the SLAM algorithm can collect trajectories of sensor(s) and map structures in

coordinates whose origins are placed on positions of the sensor(s). Accumulated errors of localization cause deformations of map information. It is important to make robust algorithms that can match and integrate incomplete maps despite of the occurrence of accumulated errors. To build such algorithms, geometry and statistics are expected to play important roles.



(a) Data A (b) Data B (c) Merged result from Data A and Data B

Figure 1 Incomplete mapping results and their merged results
(from https://www.giho.mitsubishielectric.co.jp/giho/pdf/2019/1902106.pdf)

Technical Background:

The basics of matching between incomplete maps exist in a “map matching algorithm” that estimates routes from rough trajectories by comparing them with a complete map. Usual GPS sensors can detect their own positions, but the results are in low precision and frequency to determine the route accurately. Map matching is an algorithm which estimates accurate routes from trajectories with errors and complete maps (cf. Figure 2).

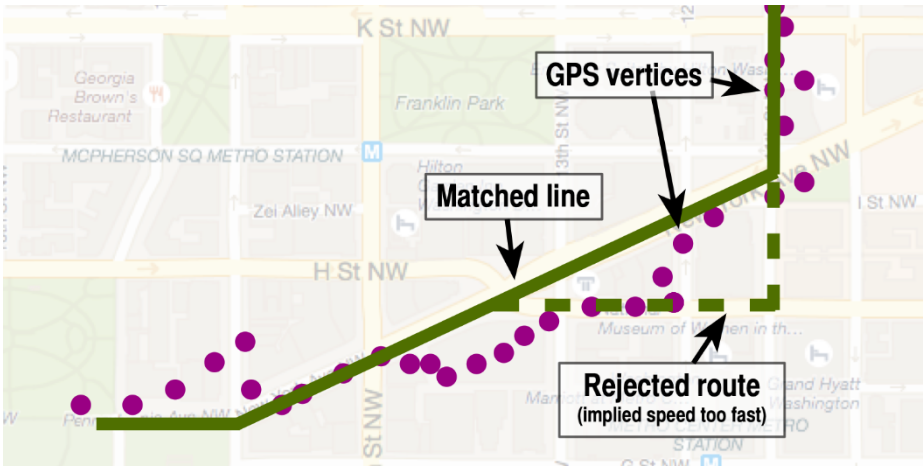


Figure 2 Map matching overview (from GitHub: amillb/pgMapMatch)

Map matching algorithms are made from considering not only the distance between trajectories and roads but also graph structures. For example, the road that is far from the current position can be matched as the true route when the road is connected with past and future routes. Therefore, several methods that use local and global geometries and/or probabilities are proposed as map matching algorithms.

Map matching algorithms are often proposed by implementations and evaluations (bottom-up approach), and there is no best method for map matching. Matching algorithms between incomplete maps are often made differently by different companies. In this project, it is expected to construct a comprehensive mathematical formulation for this task based on top-down approaches.

Expectations:

In this project, we consider how to build and evaluate matching methods between incomplete maps based on local and/or global geometries such as order, divergence, and metrics by beginning with traditional map matching algorithms. Especially, it is better to consider not just the implementation, but also a comprehensive mathematical formulation to guide the implementations. For this purpose, it is expected to use topologies and so on as new points of view for the task.

If the formulations will be made, the way to integrate matched parts also becomes our target. The integration may need to consider statistics such as Bayes filtering depending on measurement errors.

Requirements:

We assume basic knowledge of Euclidian geometry and manifold in treating geospatial information. Additionally, knowledge of graph theory and topological geometry for global analysis, and Riemannian and other differential geometries for local analysis would be beneficial. Moreover, knowledge on Bayesian statistics and Bayesian filter (corresponding to map fusion), and stochastic models should be useful for the integration of matched maps.

Recommended Reading and References:

[1] 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.

[2] 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.

[3] 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.

[4] Lou, Y., Zhang, C., Zheng, Y., Xie, X., Wang, W., & Huang, Y. (2009, November). Map-matching for low-sampling-rate GPS trajectories. In *Proceedings of the 17th ACM SIGSPATIAL international conference on advances in geographic information systems* (pp. 352-361)

[5] Teng, W., & Wang, Y. (2019). Real-time map matching: A new algorithm integrating spatio-temporal proximity and improved weighted circle. *Open Geosciences*, *11*(1), 288-297.