Best Practices for Surveying and Mapping Roadways and Intersections for Connected Vehicle Applications

Task 4 Report: Map Representation Updating

Executive Summary: It is certain that the infrastructure and roadway features will change over time, particularly for corridors that are heavily utilizing connected vehicle technology. Therefore, once a map database is established (as described in Task 3), a key issues is how easily can it be updated to accommodate changes in the infrastructure, the introduction of new mapping techniques, or the desire to map additional features. In this task report, we briefly describe different possible update technologies and approaches.

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I. Introduction

As described in Task 3, roadway feature maps are necessary to enable collaboration between vehicles and with the infrastructure in Connected Vehicle (CV) applications. Therefore, detailed roadway feature maps will need to be developed, maintained, and communicated consistently. Successful global commercialization of products incorporating high-accuracy digital maps will require a standard digital map representation of the roadway features and attributes. The roadway environment is constantly changing based on many factors; in addition, the roadways themselves, along with the continental plates on which they sit, are also moving. Therefore, in addition to having spatial continuity across large areas, uniformity between developers/users, and an efficient data representation, high-accuracy maps databases will need to be updatable. Given the need for the maps to be updateable, various interesting questions arise:

1) How will the need for local map updates be detected or communicated to the map manager?

2) How will local map updates be integrated into the map database efficiently while maintaining spatial continuity?

3) How can data integrity be assured if map updates are obtained from different sources?

This section discusses the considerations and methods to address these questions and maintain maps for utilization in a connected vehicle environment. A suitable approach and methodology is presented that utilizes data and methodologies currently available.

II. Different Methods of Data Collection

For roadway map-building there are two main methods of information data collection:

- ***Direct –*** Examples of direct methods include: human surveys, photogrammetry, stationary terrestrial laser scanning, mobile terrestrial laser scanning, and aerial terrestrial laser scanning. Each of these involves direct detection and calibration of roadway feature locations. For further detail, see the Task 1 research report of this project. Direct methods are performed by trusted entities either as employees or contractors; therefore, their data have a high-level of integrity and accuracy. These direct methods typically provide the best data, however the data collection can be expensive and time consuming. Scheduling is either periodic or by request. These direct methods are typically used by governmental entities and various companies (e.g., Mandli, HERE, CivilMaps).

- ***Indirect (or inferred) –*** The main example of an indirect method of map data collection is *crowd-sourced* data, which for roadway mapping applications refers to the accumulation of sensor trajectory data from the millions of connected vehicles and/or users driving on the nations roadways. The "sensors" in this case could be cell phones, navigation sensors within the vehicle, or standardized Basic Safety Messages (BSMs). This crowd-sourced method supplies huge quantities of sensor trajectory data from which it may be possible to mine different types of information about the roadways, such as lane centerlines and intersection stop bars. Of particular importance, these crowd-sourced methods can provide data useful for the *prompt* detection of changes to the roadway infrastructure. It is important to note that any map information extracted from crowd-sourcing is inferred, because there is no direct measurement of the sensor location relative to the roadway features. For example, tight bundles of similar trajectories might be inferred to represent lanes. Frequent stopping locations nearest to an intersection ingress point for such a bundle could be inferred to be a stop bar location. Frequent paths through intersections could be processed to infer ingress-egress lane connectivity. Indirect methods can accumulate data rapidly at very low cost. While the data integrity of each sensor may be suspect, the expectation is that statistics of the huge data set are very difficult for a small number of users to affect. The potential limiting factors are that the accuracy of the measured data by the inexpensive user sensors and validity of the various inferences are uncertain. Crowd-sourced methods have been investigated by various university research groups and commercial entities, such as, TomTom Inc.

III. Proposed Updating Technique

Experience has demonstrated that these direct and indirect methods are complementary, with each having a role to play, as depicted in Figure 1. In this figure, the red arrows depict unprocessed sensor data. When compared to the master roadway GIS database (via the gold arrows), the sensor data are processed to detect, calibrate and map roadway features and information that can serve as map updates. These suggested map updates (blue arrows) are recommended to a decision processor that may make comparisons between the direct and indirect data sources and the master roadway GIS to determine whether or not to accept the recommendations for incorporation or to schedule a local survey using direct methods (green arrow). One example is the crowd source data indicating a connection between two roadways that is not represented in the database, which could automatically trigger a direct survey for that location.

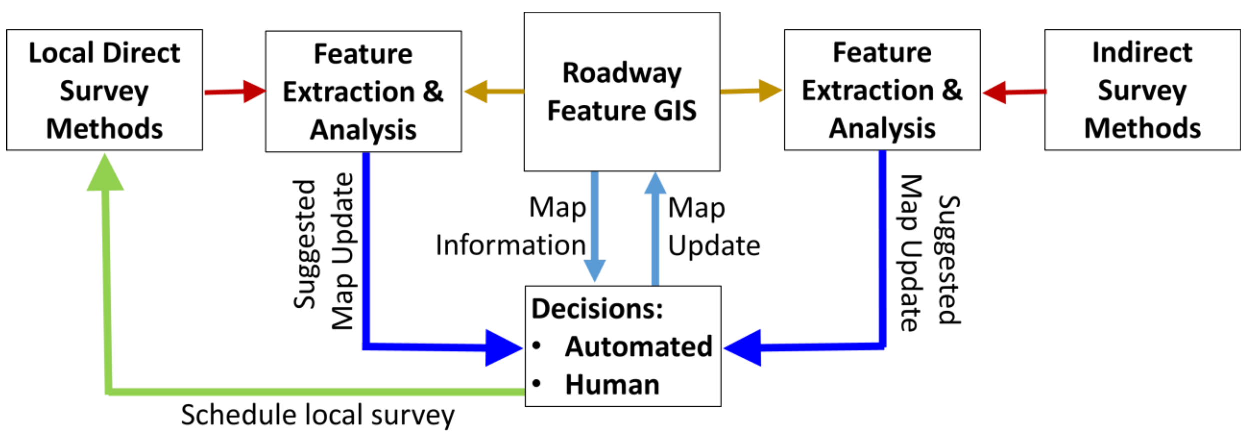

Figure 1: Complementary nature of Direct and Indirect map production methods.

Other tasks in this research project describe in detail how the LIDAR-based survey method collects data, followed by a filtering a feature extraction process. It has been shown how a mapping data set can be created (e.g., SAE J2735 map standard) going left to right in Figure 1. In addition, crowd-sourced trajectory data from connected vehicles can be filtered followed by feature extraction, creating similar map features, as illustrated going right to left in Figure 1. Because these methods are independent, they can be used for data and map validation, as well as for triggering a need for updating if the two results do not agree.