Bayesian route choice inference using Bluetooth technology

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Abstract

The emerging problem of traffic congestion in metropolitan cities generates the necessity for a better comprehension of how travellers move along the network. Traditionally, travel demand information is obtained through paper-based methods such as household surveys or intercept surveys. Although these methods provide detailed information, their high costs do not allow to keep the data regularly updated. Other traffic data collection methods, such as loop detectors do not provide details regarding the vehicles routes and license plate recognition require high data processing costs. With a complete knowledge of the travel demand patterns it is possible to calibrate more detailed and reliable models, design traffic management schemes and support transport planning, among other objectives. It is necessary then to develop and apply new methods to obtain travel demand data with high details and lower costs.

Bluetooth technology can be used to track specific vehicles by their MAC address; this can be done by installing Bluetooth detectors at selected intersections of a study area. The advantages of this technology are its low cost, ease of implementation and quality of the resultant data. Each detector can registry the unique MAC address of the vehicles equipped with Bluetooth technology, timestamp and position of the antenna. This work consider that all detections have been filtered to delete multi detections on the same vehicle (two phones for example) and mistakes on the data. Based on these detections, it could be possible to track vehicles within the study area. However, an equipped vehicle is not necessarily detected at every intersection as detection probabilities depend on many factors such as weather conditions, nearby infrastructure or vehicles speeds. This way, given the lack of perfect information, it is necessary to infer the most likely routes chosen by those vehicles.

This study presents a methodology to infer route choices in a transport network based on Bluetooth information. This is achieved by reconstructing paths between two consecutive Bluetooth detections from the same vehicle. It should be considered that when a vehicle travels between these two detection points, it might have not been recorded by other antennas by which the vehicle is passed by. Choice probabilities for each route between these detections points are obtained. These probabilities consider the number of missed detections for each route, the observed travel time and the travel time distribution of all vehicles following those routes at the same time interval. Once the choice probabilities between two successive detections are obtained, it is possible to infer the overall route choice probability from origin to destination by repeating the same process for every pair of successive detections.

The methodology has two steps: (i) a pre-load of information to the network and (ii) a route inferring. To understand the methodology, consider a study area with Bluetooth detectors installed in some intersections of the real transport network. A theoretical network is created considering intersections with antennas (nodes) and directional streets (links).

In the first step, with the collected Bluetooth data, a distribution for the time spent by the vehicles at each intersection is calibrated. This time is defined as the difference between the last and first detections of a vehicle at the intersection. Similarly, travel time distributions between intersections are obtained as the difference between the last detection of the vehicle in the upstream detector

and the first detection in the downstream detector. Both types of distributions are calibrated for different periods of the day.

The second step consists on inferring the most likely routes between each pair of consecutives detections. To do this analysis it is necessary to list the possible routes among these detection points. Then, A calibration of travel time distribution for each route are made by convolving the travel time and the spent time distributions of all links and nodes that belong to individually route. Finally, it is possible to obtain the choices probabilities based on (i) the number of detectors per path and (ii) a Bayesian inference over the travel time distributions and the observed travel time of the vehicle on consecutive detections. The second step is repeated for each pair of consecutive detections of the vehicle to build the entire route.

To test the methodology, an AIMSUN simulation is perform considering different networks; these networks differ on the quantities and locations of detectors, to show the robustness of the model in different scenarios. As in each simulation the actual routes taken by the vehicles are known, it is possible to assess the performance of the proposed methodology.

Keywords
Bluetooth technology, Network analysis, Route reconstruction, Bayesian inference.