Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 11 (2015) 218 – 226

Transportation Research Procedia

www.elsevier.com/locate/procedia

10th International Conference on Transport Survey Methods

Stop Detection in Smartphone-based Travel Surveys

Fang Zhao [a]*, Ajinkya Ghorpade [a], Francisco Câmara Pereira [a]

Christopher Zegras [b], Moshe Ben-Akiva [b]

[a] *Singapore-MIT Alliance for Research and Technology, 1 CREATE Way, #09-02 CREATE Tower, Singapore 138602*
[b] *Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA, 02139, USA*

Abstract

Future Mobility Sensing (FMS) is a smartphone-based travel survey system that employs a web-based prompted-recall interaction to correct automatically inferred information. A key component of FMS is a stop detection algorithm that derives the users' activity locations and times based on the raw data collected by their phones. Output of this algorithm is presented in the Activity Diary for the users to validate, and its accuracy has a significant impact on user burden. In this paper, we present FMS' stop detection algorithm and its performance during testing by volunteers and public users during a large-scale field test.

Peer-review under responsibility of International Steering Committee for Transport Survey Conferences ISCTSC

Keywords: smartphone-based travel survey; automated travel survey; stop detection; prompted-recall

1. Introduction

GPS-based travel surveys have gained popularity in the recent years as they can record accurate time and geographic information of users' travel. While such surveys have many advantages over traditional surveys, they suffer from several limitations: high costs, users might forget to bring the logger when they travel, and unavailability of GPS signal in certain areas [Bohte and Maat (2009), Stopher *et al.* (2007), Oliveira *et al.* (2011), Stopher and Wargelin (2010)]. With the advancement of mobile technology, smartphones are becoming an attractive alternative

* Corresponding author. Tel.: +65 6601 1547; fax: +65 6684 2118.
E-mail address: fang.zhao@smart.mit.edu

Peer-review under responsibility of International Steering Committee for Transport Survey Conferences ISCTSC
doi:10.1016/j.trpro.2015.12.019

to GPS loggers for travel surveys. Besides GPS sensor, many smartphones nowadays are equipped with multiple other sensors, such as Wi-Fi, GSM, and accelerometer, that can provide additional information on the user's travel behaviour. The phone is almost always charged and carried by the user. And as the device belongs to the user, the cost of conducting such surveys is lower. These attributes make smartphones ideal "life-loggers".

We developed the Future Mobility Sensing (FMS) system, a smartphone and web prompted-recall based travel and activity survey system [Cottrill *et al.* (2013)], which uses an app (available for both Android and iPhone) to automatically log and upload sensor data from users' phones. The uploaded raw data is processed in the backend to construct the user's activity diary, i.e., we infer users' stops, modes of transportation, and activities. The activity diary is then presented in a user-friendly web-interface in a prompted-recall manner for user validation. FMS is a next-generation travel behaviour survey system that leverages pervasive smartphones, advanced sensing and communication technologies, and machine learning architecture. It delivers previously unobtainable range of data reflecting what people do, not what they say they do. We field tested FMS in Singapore in conjunction with Singapore Land Transport Authority's (LTA's) Household Interview Travel Survey (HITS) 2012. The test recruited more than 1500 users and produced a large set of rich and detailed travel/activity data that has been validated by the respondents [Carrion et al., 2014].

From our usability tests as well as the field test, it is observed that the accuracy in stop detection is key to users' validation quality [Ghorpade et al., 2014]. A user's comprehension and correct usage of the activity diary depend mainly on the list of stops presented, and most users are reluctant to change system-generated stops. In addition, the detected stops segment the GPS traces into "trips", and errors in them will impact the mode detection algorithm.

The problem of stop detection is a very challenging one. With perfect GPS information, the task of detecting stops would be straightforward. However, in practice, there are many cases, such as densely built up areas, indoors or underground areas etc., where there is only noisy low-accuracy GPS signal or even no GPS signal. In addition, in order to preserve battery power, we choose not to continuously acquire GPS signal even when it is available. In the past GPS-based travel surveys, stop detection were done by heuristic rule based algorithms [Bohte and Maat (2009)] or with the help of visual inspection [Stopher and Wargelin (2010)]. On the other hand, research work has been carried out on detecting the "places of interest" for individual users based on smartphone data [Montoliu and Gatica-Perez (2010), Wan and Lin (2013)], although they are not specifically designed for the purpose of travel surveys. Montoliu and Gatica-Perez (2010) proposed a two-level clustering algorithm for detecting the stops, and tested it with Nokia N95 phones by eight users. More recently, Wan and Lin (2013) focused on "life-space" characterization and proposed a processing procedure to estimate user's life-space. This procedure was tested using data collected by one subject in four months.

In FMS, we need to generate user stops in real time and cater for a wide range of phones available in the market. We started with a simple rule-based approach, then introduced various heuristic methods to overcome issues encountered in the practical settings. We take into consideration inputs from GPS as well as GSM, Wi-Fi, and accelerometer. In this paper, we present the stop detection algorithm used in FMS, discuss some of the practical considerations, and demonstrate its effectiveness in the field test.

The rest of this paper is organized as follows. Section 2 gives an overview of the FMS system. Details of the stop detection algorithm are presented in Section 3. The performance of the algorithm in our field test is discussed in Section 4, followed by the conclusions in Section 5.

2. FMS overview

FMS consists of three separate but inter-connected components – the smartphone app that collects the sensing data; the server that includes the database as well as the data processing and learning algorithms; and the web interface that users access to view and validate the processed data and respond to additional questions to supplement the validated data. The three components and the flows of data among them are shown in Fig. 1.