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Workshop synthesis: New developments in travel diary collection systems based on smartphones and GPS receivers

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Abstract

This workshop examined the state of the art of existing travel diary collection systems that make use of GPS data in relationship to the needs of the practitioners that collect and analyze travel diaries. While the new data collection methods are a promising alternative that can collect both data on previously ignored demographic segments as well as short trips that are usually forgotten by respondents, they do not solve all the issues the traditional methods are prone to, and also introduce new issues on their own. The workshop participants have identified, discussed and summarized the most pressing concerns regarding the use of new travel diary collection systems based on smartphones and GPS receivers.

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Keywords: travel surveys; current status; semantics; performance; usability; applications.

1. Introduction

We have observed a decreasing response rate for traditional travel diary collection methods and an increasing need for a more accurate spatio-temporal description of how people travel over longer periods of time. As a response, scientists proposed systems that automate the collection of travel diaries using devices with location sensing capabilities such as smartphones and GPS receivers. This comes as a natural step forward that has already proven to be complementary to the traditional collection methods.

In the preceding conference held in 2014, there were two workshops closely related to the current one: 1) "Conducting travel surveys using portable devices – role of technology in travel surveys" (Mohammadian and Bricka, 2015), and 2) "Conducting travel surveys using portable devices – challenges and research needs" (Bhat, 2015).

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Mohammadian and Bricka (2015) identified both the short-term needs and the long-term research opportunities of methods that make use of portable devices. Synthesizing the best practices for travel diary collection methods, and developing methods to compare these methods constitute the short-term research needs. Privacy limitations and concerns, and increasing survey participation were identified as the core long-term research opportunities. The current workshop addressed the short-term research needs where a list of best practices for travel diary collection systems was proposed and accepted by the participants and different methodologies to compare collection systems were discussed albeit accepting that there is no one size fits all solution (Prelipcean et al. 2015, Stopher and Shen 2011, Schuessler and Axhausen 2009)

Bhat (2015) particularly focused on the challenges of generating activity travel diaries from collected trajectories, data fusion from multiple sources (e.g., GPS, accelerometer, transit feeds), and the representativeness issues when collecting travel diary solely by portable devices. In the current workshop, Lei et al. (2017) proposed a new segmentation method for detecting stop episodes within a trajectory and the participants have discussed the issues of generating activity travel diaries from collected trajectories touching on some of the recent research trends (Chung and Shalaby 2005, Prelipcean et al. 2016, Zheng et al. 2008).

The current workshop continues the previous two workshops by: 1) proposing solutions for aforementioned problems, 2) continuing the discussions and research trends established previously, and 3) identifying new issues that became pertinent or were introduced by using new data sources.

2. Workshop focus

The workshop consisted of three sessions of two hours each. After the self-introductions of each workshop participant and the introduction of workshop themes by the workshop chairs, the first session was mainly devoted to the two oral presentations and short introductions of posters associated with the workshop (See Appendix A for oral presentations and Appendix B for posters, respectively). Adrian C. Prelipcean presented the first paper (Prelipcean et al. 2017), which compared the available travel diary collection systems using smartphones and GPS loggers. More than ten available travel data collection systems were compared for technical specifications and the segmentation, inference and data collection capabilities. It is found that most of the systems developed after 2010 do not have any major differences from a system perspective, while they have been developed internally thus independently with each other. Vivian Daigler presented the second paper (Stopher et al. 2017), which compared smartphones and GPS loggers as travel diary collection system. It is found that GPS logger is preferable to smartphones in terms of the recruitment and compliance rates. The primary reason was the anxiety for downloading the smartphone app, which would provide a two-way portal to the personal data stored on their smartphones. The secondary reason was that not all teenagers own smartphones. It should be noted that the demographics of the smartphone households were significantly different, thus warranting the consideration of using a hybrid approach in future household travel studies by offering both GPS loggers and smartphone data collection.

Breakout small group discussions and synthesis took place in the second and third sessions, respectively. The workshop participants discussed and debated on the timely topics of travel diary collection methods, such as: 1) the current status of travel diary collection systems based on smartphones and GPS receivers, 2) the methodologies to extract semantics from GPS trajectories and auxiliary data, 3) performance and usability considerations for using smartphones and GPS receivers to collect data for generating travel surveys, and 4) the potential applications of finer spatio-temporal granularity survey data.

3. Workshop outcomes and research directions

1.1. The current status of travel diary collection systems based on smartphones and GPS receivers

The landscape of travel diary collection systems has drastically changed over the last two decades from having few alternatives to collect travel diaries besides traditional paper and pencil collection, to having a plethora of

systems that use smartphones to collect the locations of individuals. Deciding on data collection tools is usually the first step of travel diary collection studies and the usual decision is to design and implement a data collection system. While most systems have been proven to work for a particular application or suite of applications, relatively few systems have been used to collect travel diaries on a wider scale, in different geographical regions or by different research groups. Multiple pressing concerns that were raised on this topic, such as:

Lack of ground truth: In the lack of a travel diary collection method or system that can guarantee that all the activities of a group of individuals are captured, scientists are left with analyzing potentially complementary travel diary collection methods. As previous research has shown, while the system that generate travel diaries from GPS trajectories successfully collect a subset of the trips that travelers forget to declare in paper and pencil or interview based collections, there are no modern systems that collect all the trips collected via traditional travel diaries from all demographics. As such, it is difficult to compare different travel diary collection methods since they cater for different demographics and, ultimately, end up collecting complementary data. Since no set of observations is perfect, we have to define what is acceptable truth rather than focusing on achieving a theoretical ground truth.

Sample representativeness: As previously mentioned, the traditional travel diary paper and pencil collection methods have seen a continuous decrease in the response rate of individuals. On the other hand, collecting data via smartphones and asking travelers to confirm attempted inferences of travel diaries via a user interface (e.g., in a web-browser, on a smartphone app) is a viable alternative for a group of previously unrepresented individuals. However, while collecting travel diaries via both paper and pencil as well as smartphone / GPS based systems seem to offer a representative sample, the question that science stopped asking is whether we should redefine the meaning of a “representative sample”. Paper and pencil, interviews and smartphone / GPS based travel diary collection methods and systems do not capture the behaviour of individuals that cannot use one of the aforementioned means in their full capacity to declare their travel (e.g., individuals suffering from dyslexia, color-blindness, visual impairment or individuals that live in poverty or in areas where no dedicated budget is available for collecting travel diaries).

Minimizing cost of travel diary data collection: There is an overall consensus that collecting travel diaries is an expensive endeavor and it is only available for researchers and municipalities with a sufficient budget. As an attempt to fairly distribute the opportunity of doing research to all research groups, researchers have open sourced travel diary collection systems (Prelipcean et al. 2014), or are planning in doing so. However, while the developments costs are minimized, the operational (e.g., server hosting, user support, etc.) and distribution (e.g., inviting travelers to collect data) costs are still viewed as an impediment. Cheaper (ideally free) alternatives to the current operational and distribution activities should be documented more thoroughly and researched more systematically outside of an usually project-specific scope.

Tradeoffs between using smartphones and using dedicated GPS receivers: Deciding on collecting data via either GPS receivers or via smartphones is usually a sensitive choice that can be summarized in terms of cost. Collecting data with GPS receivers (or loggers) results in a high distribution cost and low development cost, whereas collecting data with smartphones results in a low (usually no) distribution cost and high development cost. Interestingly, while there is research that shows that the data collected from GPS receivers has a higher spatial accuracy (Montini et al. 2015), there is no conclusive research that analyzes whether an increase in the higher spatial accuracy corresponds to an increase in the classification accuracy for doing travel mode, purpose or destination detection. As such, deciding on a superior data collection device depends on the specifications of the project, although the smartphone associated costs make more sense economically for collections targeting a large number of individuals.

1.2. The methodologies to extract semantics from GPS trajectories and auxiliary data

Continuous trajectories in the form of a series of points can be collected using smartphones and GPS receivers, but these raw data cannot be further utilized without extracting meaningful information from the trajectories. The extraction of meaningful information typically consists of several steps, which include the identification of trip ends and trip segments, and the inference of travel modes (for trip segments), destination and purpose (for trips). Different types of algorithms (e.g., rule-based algorithms, probabilistic models, machine learning methods, etc.) that make use of auxiliary data (e.g., land use, general transit feed specification – GTFS –, transportation networks, etc.) are proposed as potential solutions for each of the aforementioned steps. Some of the issues that were raised on this topic were:

Semantics difficult to extract: Although researchers developed methodologies to extract different aspects of travel, during the workshop, the participants identified semantics that are difficult to extract, e.g., pick-up and drop-off behaviour, the number of passengers in car, health condition, etc. Pick-ups and drop-offs have a very short stop time associated with their activities, which makes them difficult to detect, and, as such, risk losing information that is important to understand activity chains and inter-personal interaction (e.g., family members, friends and colleagues). The number of passengers per car can be used to compute efficiency in terms of person-kilometer, as well as the inter-personal interaction. Similarly, health conditions significantly affect the activity-travel behaviour, although the extent of this is unclear.

Insufficient scope of performance measures: The current performance measures used for segmenting a trajectory into trips and triplegs are simplistic in their nature: they count the number of detected trips / triplegs and compare the number with the actual number of trips / triplegs. This is an approach that fails to take into account the fact that failing to detect a stop episode affects two trips / triplegs, which in turn affects the spatial and temporal attributes of the derived trips and triplegs. As such, it is possible to have relatively high (over 90%) precision and recall values for tripleg detection and at the same time have gross values for average speed / duration of the travel modes. As a solution, it is worthwhile looking into methods that penalize space and time errors to complement the measures based on counting the number of detected trips / triplegs (Prelipcean et al. 2016).

Classification methods that leverage the availability of auxiliary data sources: There is a common trend in travel mode detection and purpose inference of using data sources that are available to a restricted number of geographical areas (e.g., public transportation networks, transit feeds for buses and subways, real time location of taxis, etc.) While these features greatly benefit the accuracy of the classifiers, it also limits the applicability of the classifiers to only the regions where such data are available at the same granularity as in the original case study. This is not a reasonable assumption, since it is generally difficult to get high quality curated data in most regions of the world. To overcome this, a new type of classifiers that perform well on a baseline set of features derived only from collected raw data (i.e., GPS trajectories and / or accelerometer readings) should be developed to easily integrate rich data sources to improve their classification accuracy. In this scenario, a classifier would still perform reasonably in any new area and whenever a new data source is available, it would easily integrate it, without making it unusable until all the desired data sources are available.

1.3. Performance and usability considerations for using smartphones and GPS receivers to collect data for generating travel surveys

Most researchers that develop new travel diary collection systems try to identify the suitability of their new system by case studies in which a group of participants is declaring / collecting travel diaries using a widely accepted traditional method (i.e., paper and pencil) and a new proposed method. Comparing the travel diaries generated by the two systems for the same users can give valuable insight into the superior method. Because of the

unique aggregated information contained by travel surveys, it is difficult to identify the performance metrics one can use when comparing different travel diary collection methods, and in general authors rely on "matching" corresponding trips from the travel diaries collected by multiple systems. Most studies have found that while there is no clear alternative that always collects more robust data than the paper and pencil method, there are cases in which the paper and pencil suffers from drawbacks (Golob and Meurs 1986, Murakami and Wagner 1999, Pierce and Giaimo 2003). Such cases are mostly due to participants forgetting to declare short trips, refusing to declare actual trips or failing to relate to the scientific definition of trip (e.g., considering doing shopping while on the way home from work as part of the trip from work to home). Multiple pressing concerns that were raised on this topic, such as:

Battery consumption: One of the main concerns of installing a travel diary collection purposed app on a smartphone is the effect it will have on the battery of the smartphone. While it is common practice to use accelerometer to detect when people are moving and only collect data if there is movement worth collecting (Prelipcean et al. 2014, Liao et al. 2017), the trend of presenting information on travel diaries in the smartphone app designed for data collection introduces a new source for draining the smartphone battery. Whereas the GPS collection has the highest impact on battery drainage (in most cases), the composite effect of GPS drainage accompanied by the screen being turned on can lead to an unacceptable battery consumption for users. A solution is to investigate both better ways to collect GPS data as well as better user interface apps that do not require users to spend long periods of time annotating data on their phone.

Getting users to collect data: Usually, the strategies employed to on-board new users to start using a travel diary collection app are undocumented in the scientific literature. This is problematic because of the potential security breaches that it can introduce (Shabtai et al. 2010) and because it introduces a fake perception of costs involved to distribute an app. Currently, around 2000 users can be on-boarded to try new apps without any costs by using freely available app distribution platforms (https://get.fabric.io/ or https://developer.apple.com/testflight/).

Varying accuracy of GPS records between multiple devices: It is common when using multiple devices for collecting data to obtain a substantial variation in the spatial accuracy of the collected GPS traces. In particular, collections designed for operating systems such as Android that are used on a large variety of hardware by different phone manufacturers are predisposed to this problem. However, as previously mentioned, there is no clear indication regarding the correlation between spatial accuracy of GPS records and the classification performance of inference methods, which could mean that a simple threshold could be used to filter out noise.

Improve user interface and user experience: While the paper and pencil travel surveys are a preferred medium to collect data from older age groups, the smartphones are a plausible medium to collect data from younger age groups. However, neither method allows for collecting data from people with different conditions that prevents them from writing / interacting with a screen. Furthermore, none of the existing user interfaces are simple enough to be used by people without some type of training. The research community should start cooperating with UI / UX experts to improve the interface to a point where it is difficult to erroneously declare something. One of such ideas raised during the discussion is to use verbal prompts and annotations performed with smartphone voice assistant software (e.g., Siri – https://www.apple.com/ios/siri/, Google Now).

1.4. The potential applications of finer spatio-temporal granularity survey data

One of the interesting aspects of generating travel diaries from data collected by smartphones and GPS receivers is the abundance of raw and auxiliary data available for analysis. The traditional travel diaries do not contain information regarding the actual route, waiting times, or any detailed tripleg information for travelers, and the availability of such data contrasts the usual research status quo, i.e., we now have more data than needed for the task at hand. While this raises ethical and privacy issues due to the high spatio-temporal granularity of the data, it is

important to identify the advantages of more detailed collected data. Multiple pressing concerns that were raised on this topic, such as:

Data sharing: During the workshop, the participants suggested an option for data sharing between institutes: have an official data repository where data are stored at the highest level of detail and then shared with other institutes only at a level of aggregation that preserves privacy and is relevant for the scope of why the data sharing request was made.

Abstraction level: Some participants found that establishing an appropriate abstraction level for collected GPS data to avoid redundant data collection is needed. This would make it easier to analyze data since only the meaningful abstraction (e.g., a trip / a tripleg) would be stored. However, this makes it difficult to reuse the data for future research that potentially need data stored at the highest level of detail. As such, a potential solution would be to develop a widely accepted data model and interface to share raw collected data that would allow for data to be stored at the highest level of detail available and shared at a level of abstraction relevant for the purpose. This is related to the aforementioned point for data sharing.

User consent: Alas, one of the major issues with data collection and storage is usually reduced to user consent. In particular, the fact that any reuse of collected data should be accompanied by a new signed consent form makes it difficult to share data across different research projects. Unfortunately, while all participants were interested in discussing about the topic and understanding the implications of user consent, there were no legal experts present to answer any of the questions.

4. Conclusions

While the research community is continuously investigating new methods to collect travel diaries, which include developments in machine learning, artificial intelligence and other types of classifiers that can transform a stream of GPS locations into travel diaries, the legal implications of sharing highly sensitive data such as GPS traces have made it next to impossible to compare different travel diary collection systems. As such, one of the recommendations as a result of this workshop is to investigate the legal implications of obtaining a benchmark dataset that can be used by all scientists to objectively compare travel diary collection systems and methods. The second and last recommendation regards the improvement of collaborations and information exchange in between research groups and / or private companies that maintain and develop travel diary collection systems. It is not uncommon for a travel diary collection system (or solely a GPS collection system) to be developed because it would appear to make more sense economically than to pay for an existing solution. Ideally, this suggestion would materialize in more researchers licensing their work under open source licenses that would make their contribution free and accessible to use for everybody

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Appendix A. Papers presented during the workshop

Collecting travel diaries: current state of the art, best practices, and future research directions. Authors: Adrian C. Prelipcean, Yusak O. Susilo and Gyözö Gidofalvi

Smartphone app versus GPS logger: A comparative study. Authors: Peter Stopher, Vivian Daigler and Sarah Griffith

Appendix B. Posters associated with the workshop

Trip validation interfaces of smartphone-based travel survey solutions put to test: A comparative usability study. Authors: Angela Ferreira, Norbert Braendle, Peter Widhalm and Cristina Olaverri-Monreal.

On the user experience and performance of smartphone apps as personalized travel survey instruments: Results from an experiment in Toronto. Authors: Chris Harding, Zoe Tenteng Zhang, Siva Srikukenthiran, Khandker Habib and Eric Miller

Oregon Metro tour-based freight model data collection: Lessons learned. Authors: Mark Fowler, Maren Outwater, John Gliebe and Courtney Nielson

Using GPS data from a fleet of shared free-floating cars to estimate parking search time. Authors: Jean-Simon Bourdeau, Grzegorz Wielinski, Catherine Morency, Nicolas Saunier and Martin Trépanier

Identification of activity stop locations in GPS trajectories by DBSCAN-entropy method combined with support vector machines. Authors: Lei Gong, Toshiyuki Yamamoto and Takayuki Morikawa

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