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MEILI: A travel diary collection, annotation and automation system

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ABSTRACT

The increased interest in the automation of travel diary collection, together with the ease of access to new artificial intelligence methods led scientists to explore the prerequisites to the automatic generation of travel diaries. One of the most promising methods for this automation relies on collecting GPS traces of multiple users over a period of time, followed by asking the users to annotate their collected data by specifying the base entities for a travel diary, i.e., trips and triplegs. This led scientist on one of two paths: either develop an in-house solution for data collection and annotation, which is usually an undocumented prototype implementation limited to few users, or contract an external provider for the development, which results in additional costs. This paper provides a third path: an open-source highly modular system for the collection and annotation of travel diaries of multiple users, named MEILI. The paper discusses the architecture of MEILI with an emphasis on the data model, which allows scientists to implement and evaluate their methods of choice for the detection of the following entities: trip start/end, trip destination, trip purpose, tripleg start/end, and tripleg mode. Furthermore, the open source nature of MEILI allows scientists to modify the MEILI solution in compliance with their legal and ethical specifications. MEILI was successfully trialed in multiple case studies in Stockholm and Gothenburg, Sweden between 2014 and 2017.

1. Introduction

Understanding how people behave has been the bedrock of social science since its inception. As with most branches of science, an objective and non-biased analysis is dependent on the prowess of the analysts and on the quality and representativeness of the data that is analyzed. As such, scientists have focused on developing both analysis methods and data collection tools as an effort towards a more reliable understanding into how people behave.

In particular, transportation science studies people's travel behavior by analyzing how people make the travel choices to fulfill their daily schedule. The most common way to obtain the information on how people allocate their travels throughout the day has been via the collection of travel diaries. A travel diary is a sequential description of what a traveler has been doing during a predefined time frame (of usually one day), where a respondent describes her trips and triplegs. A *trip* describes an activity and, as such, contains information about: 1) the start and stop time of a trip, 2) the origin and destination of a trip, 3) the length of a trip, 4) the purpose of the trip, and 5) how the user traveled between the origin and the destination. Similarly, a tripleg represents the part of a trip that was traveled solely via one travel mode, and contains information about: 1) the start and stop time of a tripleg, 2) the start and stop place of a tripleg, 3) the length of a tripleg, and 4) the travel mode. While the amount of information contained by a tripleg is undeniably useful, it is difficult to design an effective survey that can prompt users to specify all tripleg related information without increasing the survey fill-in burden and, subsequently, the drop rate (Axhausen, 2008; Prelipcean, Gidófalvi, & Susilo, 2017a; Richardson, Ampt, & Meyburg, 1995). As such, it is common practice for surveys to limit the questions regarding triplegs to the sequence of travel modes or to the main travel mode.

One of the main drawbacks of using the traditional ways of filling-in a travel survey is the response rate, which has been shown to steadily and consistently drop during the last decades (Richardson et al., 1995). This drawback is also accompanied by a declaration bias, which is partly induced by respondents forgetting to declare some trips (Stopher, 1992), and partly induced by using terms in the travel diary survey that are not common for non-experts, e.g., trips and triplegs. These drawbacks, accompanied by the surge of devices that allow for a seamless collection of data at a low cost (Prelipcean, Gidófalvi, & Susilo, 2014) have prompted scientists to investigate new ways of deriving the same information as offered by travel diaries but with a higher response rate and lower declaration bias. These new promising options try to complement or replace the traditional declaration-based travel diary

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collection with methods that extract travel diary specific information from trajectories and auxiliary datasets.

However, since these new methods are seldom tested more than once, there is a lack of convergence towards a widely accepted framework for collecting data and attaching travel diary specific semantics to the data. This downside is accompanied by a lack of thorough software and hardware documentation, as well as a lack of specifications that guided the development process, which makes most previous research difficult to reproduce.

This paper introduces MEILI[1] – a travel diary collection, annotation and automation system – and describes how MEILI was used during multiple case studies: three case studies in Stockholm, Sweden (Prelipcean et al., 2017a) and one in Gothenburg (Allström, Prelipcean, Gejdebäck, & Skoglund, 2016). The modular design of MEILI allows those interested in travel diary automation from sequences of GPS locations describing the users' movement (trajectories) fused with accelerometer readings, to modify and adapt the source code to her own needs, e.g., embedding the readings from other sensors into the trajectories, using spatial datasets that are region-specific, etc. Most components of MEILI are released as copyleft open source products as an effort to form a community around MEILI that encompasses the interests of both research and industry communities.

The remainder of this paper is structured as follows: Section 2 presents the literature review relevant for systems that attempt to collect travel diaries (manual, semi-automatic and automatic), Section 3 describes the system architecture of MEILI and its modular design, Section 4 illustrates the performance of MEILI during a real-world case study where MEILI was used to collect travel diaries from 171 respondents, Section 5 concludes the paper, and, finally, Section 6 presents the future work in this field.

2. Literature review

The traditional methods to collect travel behavior data rely on either collecting travel diaries or on collecting activity travel diaries, which slightly differ in terms of what the focus of the questions is, but ultimately result in the same output (Clarke, Dix, & Jones, 1981; Stopher, 1992). While these two types of travel behavior collection methods are the most widely used, there have been attempts on increasing the response rate (Murakami & Wagner, 1999), eliminating the response over time bias (Golob & Meurs, 1986), and diminishing the number of forgotten trips (Pierce, Casas, & Giaimo, 2003) by augmenting the collection with computer assisted telephone interviews (CATI), computer assisted personal interviews (CAPI), and computer-assisted self-interviews (CASI). For a detailed overview of these technologies, the reader is directed to Wermuth, Sommer, and Kreitz (2003) and Wolf (2006).

However, the pervasiveness of mobile phones together with the declining response rate to travel diaries has led scientist to investigate whether travel diaries can be complemented or replaced by methods that rely on collecting trajectories from users and annotate/infer travel diary semantics for the aforementioned trajectories (Wolf, Schönfelder, Samaga, Oliveira, & Axhausen, 2004; Prelipcean, Gidofalvi, & Susilo, 2015; Stopher, FitzGerald, & Zhang, 2008; Wolf, Guensler, & Bachman, 2001; Wolf, Oliveira, & Thompson, 2003). As such, a new research focus is found in deriving travel diaries from trajectories, which do not achieve, at the date of this writing, the automated generation of travel diaries from trajectories (Prelipcean, Gidofalvi, & Susilo, 2016). This is mostly due to the fact that it is difficult to develop and set up a system that allows for the collection of trajectories and their annotation into travel diaries. Furthermore, the difficulty drastically increases with the scale at which the system is supposed to collect data for, both size-wise (with regards to number of users) and region-wise.

[1] According to http://mythology.wikia.com/wiki/Meili, MEILI is the Norse god of travel.

Previous approaches rely on hiring external developers (Bohte & Maat, 2009; Greene, Flake, Hathaway, & Geilich, 2016), designing in-house tools whose source code is not released and its license is not specified and seldom reused for multiple case studies (Cottrill et al., 2013; Greene et al., 2016; Montini, Prost, Schrammel, Rieser-Schüssler, & Axhausen, 2015; Nitsche, Widhalm, Breuss, & Maurer, 2012; Safi, Assemi, Mesbah, & Ferreira, 2017; Wang, Gao, & Juan, 2017), as well as manually visualizing and analyzing the data using different Computer Aided Design techniques (Wolf et al., 2004; Stopher et al., 2008; Wolf et al., 2001; Wolf et al., 2003). While numerous systems have been developed commercially (e.g., Wolf, 2000; Kim, Kim, Estrin, & Srivastava, 2010; Cottrill et al., 2013; Berger & Platzer, 2015; Geurs, Thomas, Bijlsma, & Douhou, 2015; Montini et al., 2015; Sense.DAT - DAT.Mobility, n.d.; rMove, n.d.), to the authors' knowledge, there is no available open source solution for collecting travel diaries that is freely available for everyone to use, which impedes research progress due to the vendor lock-in.

This paper proposes the MEILI system, which is designed for collecting and annotating trajectories from large groups of users that is released under an open-source specific license, which allows scientists to collaborate on maintaining and improving the system.

3. System architecture

MEILI is an open-source system designed for the collection and annotation of travel diaries of multiple users. The design and implementation of MEILI have undergone multiple iterations, but the philosophy behind developing MEILI remained constant, i.e., MEILI should be a system that fulfills the following criteria: 1) can collect GPS locations fused with accelerometer readings in a battery efficient manner, from a large number of users, 2) allows users to annotate their collected data into travel diaries, 3) uses different machine learning techniques to aid users during data annotation stages, 4) is available to the research community, and 5) it is simple to deploy without specific expertise.

With regards to the aforementioned criteria, MEILI was designed as a typical, three-tier, Model-View-Controller that has two types of clients: a data collection component named Mobility Collector (which is further explained in Section 3.3.1) and a data annotation component named Travel Diary (which is further explained in Section 3.3.5). The primary task of the data collection component is to collect movement information from a user's smartphone in a seamless and battery efficient fashion. The primary task of the data annotation component is to allow users to annotate their trajectories with travel semantics (i.e., trips, triplegs, travel modes, trip destinations and purposes) and to display the inferred travel semantics.

MEILI has two main cycles: the data collection cycle (arrows 1 to 5 in Fig. 1) and the user annotation cycle (arrows 6 to 11 in Fig. 1). To start using MEILI, the user first needs to install the Mobility Collector (Prelipcean et al., 2014) on her personal smartphone and then register a username and password (arrow 1). After the registration, the user's smartphone can start collecting data in a battery efficient way (this is briefly described in Section 3.3.1). After the collection is started, the Mobility Collector periodically updates the collected data to the central server (arrow 3). Any upload of a batch of locations to the database prompts a middleware to form a stream of all the locations belonging to the user that are not within an inferred trip, and pushes it forward to the AI (Artificial Intelligence) component (arrow 4). The AI module then segments the stream of locations into trips and triplegs. The segmented trips and triplegs are then inserted into the database and made available to the user when logging in to the Travel Diary (arrow 5, and the second cycle).

To annotate the collected data, the user logs in via the MEILI Travel Diary (arrow 6), which prompts the database to be queried for the retrieval of the user's least recent unannotated trips and triplegs, together with a list of all available travel modes (for triplegs), a list of nearby

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