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Collecting travel diaries: Current state of the art, best practices, and future research directions

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Abstract

The amount of useful information that can be extracted from travel diaries is matched by the difficulty of obtaining travel diaries in a modern era where the response rate to traditional travel diary collection methods has seen a decrease in most countries. Prompted by this, a body of research has been dedicated to study how travel diaries can be collected via new methods, namely location enabled devices such as smartphones, that have a higher penetration rate (in terms of device ownerships and user attachment) and are both easier and cheaper to manage compared to traditional data collection method, e.g. paper-and-pencil, phone, or web-based questionnaires. This paper offers an overview of the current state of travel diary collection, a potential future state and a practical checklist for travel diary collection case studies. A thorough discussion on different pros and cons of travel diary collection methods and efforts needed for the convergence of methods to collect travel diaries for all demographics are provided. The practical checklist to aid researchers to organise case studies is based on the authors' experience and it is meant to raise awareness of difficulties that can be encountered while collecting travel surveys with automated and semi-automated systems, and how to overcome them.

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1. Introduction

Travel diaries are widely accepted as one of the proxies for getting insights into the travel behaviour of individuals and groups. The decrease in the users' response rate to traditional methods for collecting travel diaries, i.e., sending paper or web questionnaires, have prompted scientists to investigate new ways of obtaining travel diaries. Most new methods result in systems that use machine learning, artificial intelligence, or any other type of classifiers to annotate raw GPS trajectories into travel diary entities, i.e., trips and their destination and purpose, and triplets and their travel modes. However, as with most new technologies, the expectations for the automatic

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collection of travel diaries have been inflated while these technologies were at an early stage. Most previous efforts are focused on transforming a trajectory into trips or triplets, but not into a travel diary, and placed little emphasis on creating a working, robust and reliable collection system. This has led to fragmented research that focuses on narrow applications of travel diary collection, e.g., purpose, destination or travel mode inference, which contrasts the problem they are designed to solve: collecting travel diaries. The research that focused on generating travel diaries as opposed to parts of travel diaries (e.g., only trips, only triplets, only travel modes), has either focused on full automation of travel diary generation, which usually leads to a lack of ground truth data validated by users, or on semi-automation, which adds the extra logical step of asking for user validation for inferred entities. Unfortunately, the current literature does not differentiate between automated and semi-automated travel diary collection systems, which makes it difficult to identify the strengths and weaknesses of each system, as well as establishing best practices and future research directions for travel diary collection systems.

This paper aims to clarify the existing state of the art in travel diary collection systems. First, it presents an overview of the available methods and systems for collecting travel diaries. Second, it offers plausible research directions in direct relationship to the state of the art of other relevant disciplines (e.g., database management systems, machine learning and artificial intelligence). Finally, it provides a set of technology best practices for case studies that involve collecting travel diaries with automated or semi-automated systems. The set of best practices is built on the practical experience from developing and running MEILI, an open source travel diary collection system.

The remainder of this paper is structured as follows: Section 2 introduces the main types of travel diary collection systems and methods, Section 3 summarizes existing travel diary collection systems, Section 4 presents possible research directions for travel diary collection systems as well as a set of best practices on organizing case studies that involve the collection of travel diaries, and Section 5 concludes the paper.

2. Travel diary collection systems and methods

This section contains a description of the main types of travel diary collection systems and methods, as well as an overview of the steps taken when collecting travel surveys.

2.1. Steps to collect travel diaries

In general, when conducting a survey, one usually follows five main steps:

1. *Design*, where the survey administrators decide on which entities should be collected, on the appropriate means for collecting them, and on a representative user group for the case study,
2. *Distribution*, where the surveys are distributed to the representative user group via the medium chosen in step 1,
3. *Fill-in procedure*, where the participants fill in the surveys,
4. *Retrieval*, where the surveys are sent back to the administration team via the chosen medium, and
5. *Analysis*, where the collected data are analysed.

2.2. Implementation Variation

There are three main implementations of the general methodology, each with a different focus: 1. *memory-based travel diary declaration*, where most of the effort is invested in designing an easy to use and understand interface for users, who will then declare their activities based on their recollection of the day (further discussed in Section 2.2.1), 2. *automated travel diary generation*, where the effort is invested in choosing data sources (usually GPS trajectories) that classifiers can use to extract travel diary-like attributes and semantics without any need of user interaction, which can lead to a lack of ground truth if no overlap with another travel diary reporting method is used (further discussed in Section 2.2.2), and, 3. *semi-automated travel diary generation*, where the effort is invested in combining the data collection and classification used by automated travel diaries with easy to use interfaces that display to the users the inferred travel diaries and allows users to correct any mistakes made by classifiers (further discussed in Section 2.2.3).

Table 1. A comparison between different memory-based travel diary declaration methods. While the paper travel surveys offer more options for design, they are also more expensive to distribute and retrieve, and the collected data have to be centralized and digitized before the analysis step.

	Letters	Web Forms
Design	Free form design	Constraint by platform used for web-forms
Distribution	Expensive	Cheap
Retrieval	Expensive	Cheap
Analysis	Data needs to be centralised and digitised	Data already centralised

2.2.1. Memory-based travel diary declaration

The traditional travel diary collection methods rely on designing a questionnaire whose answers correspond to the travel diary entities of interest (i.e., trips with their purpose, destination, and main travel mode) and whose questions are either built around the concept of travel or around the concept of activity (Clarke et al. 1981, Stopher 1992, Prelipcean 2016). These methods rely on people declaring what they did during the study period (of usually one day) and are affected by the users' ability to remember their activities as well as the users understanding of the definitions used in the questionnaire (Axhausen 2008).

There are two main variations of memory-based travel diary collection methods: 1. travel diaries that are sent out as *letters* via physical mail, and 2. travel diaries sent out as *web forms* via email. A way to improve the quality of collected travel diaries is to provide assistance to the users while filling in the surveys (Wolf 2006), with the following most common methods: computer assisted telephone interviews (CATI), computer assisted personal interviews (CAPI), and computer-assisted self-interviews (CASI). A summary of these methods is found in Wermuth et al. (2003), Wolf (2006). While authors have declared that providing assistance to users when completing travel diaries increases the collected data quality, the costs for hiring personnel to assist users is high and this is a process that is difficult to automate using Automated Computer Telephone Interviewing (Bowling 2005). These limitations dampen the viability of this method to be used on a relatively large scale.

The main differences between surveys sent out as letters and surveys sent out as web forms is the distribution medium and cost (steps 2, 4 and 5 in Section 2.1, also summarized in Table 1). For the distribution stage, web forms are generally easier to distribute due to the simplicity of the process: send an invitation via an email with a URL to the survey. This process can reach a larger user group since one invitation email can be sent to all users at low costs (sometimes there are no costs). Contrarily, surveys sent out as letters have to be printed out and then sent out to a sample of the population, which is a costly procedure. Furthermore, the users have to send back the filled in surveys via mail, and the surveys have to be digitized or entered in an analysis-friendly form, which involves significant additional costs.

Another difference between letters and web forms is in survey design. While the letter surveys benefit from more freedom since the design can be custom made to facilitate the understanding of concepts to the users, web forms are usually restricted to a set of elements that is defined by the platform used for creating the web forms. Alternatively, one can invest in embedding custom elements in web forms by creating custom web pages connected to a central API (application programming interface), but this results in additional costs. Similarly, an often neglected aspect of travel survey design is the medium of interaction for the users, since design elements that offer a pleasant experience on paper do not offer the same experience on screen (Nakhimovsky et al. 2009). Due to the high costs and the narrow demographics that usually responds to paper surveys (*Swedish National Travel Survey* 2016, Prelipcean et al. 2017a), web forms are the main travel diary collection method, and paper surveys are sent out to particular demographic segments. However, there are down-sides for asking users to declare travel diaries based on their memory such as a decreasing response rate (Murakami & Wagner 1999), users forgetting to declare trips (Pierce et al. 2003) and response over time bias (Golob & Meurs 1986).

Table 2. A comparison between different automated travel diary generation methods. While dedicated devices collect higher quality raw data, smartphone applications can be distributed with no cost and the data are centralized.

	Dedicated devices	Smartphones
Design	Not necessary	Basic design needed
Distribution	Expensive	No cost
Retrieval	Expensive	N/A
Analysis	Data needs to be centralised	Data already centralised

2.2.2. Automated travel diary generation

The research in automated travel diary generation is prompted by the aforementioned downsides of the memory-based declarations of travel diaries and it relies on circumventing the user efforts in declaring travel diaries by collecting raw data and applying different classification methods on the data (e.g., machine learning, artificial intelligence, statistical modeling) to generate travel diaries. These methods usually collect GPS trajectories and make use of auxiliary data (e.g., accelerometer, transportation networks) to extract / annotate travel diary entities (Prelipcean 2016).

There are two main variations for the automated travel diary generation (the main differences are summarized in Table 2), which is due to the different devices used for data collection: 1. data collected via a dedicated device (e.g., standalone GPS receiver, attaching GPS and accelerometer sensors to an Arduino device), 2. data collected via a smartphone.

The main difference in between collecting data via a dedicated device and via a smartphone is mainly in the ease of distribution. Smartphones are already widely used devices with a high penetration rate and a multitude of sensors (Prelipcean et al. 2014), which makes the distribution of a data collection smartphone application desirable. Contrarily, dedicated devices are more difficult to distribute since they have to be built, sent and retrieved from the users. Similarly, users have to be reminded to carry the dedicated devices, which is not necessary for smartphones due to the already high perceived utility of smartphones by users (Chang & Huang 2015, Pew Research 2016). One important side note for dedicated devices is that in the lack of access to GSM or WiFi data connection, the access to the collected data depends on retrieving the devices from their users. This is not an issue for smartphones since the capabilities for periodically uploading data are present on most modern smartphones.

Another difference between smartphones and dedicated devices is the raw data quality collected, where there is a consensus that dedicated devices collect more accurate / precise raw data. However, while authors have investigated the difference in the quality of measurements (mainly GPS accuracy) between smartphones and dedicated devices (Montini et al. 2015), no research drew conclusions regarding whether the higher positioning accuracy of dedicated devices translates to a more accurate classification of GPS trajectories into travel diaries.

Finally, both dedicated and smartphone based data collections involve considerable development efforts. In general, if data are collected via dedicated devices, it is common to either have the same dedicated device used for collection sent out to all users (mostly the case for custom hardware solutions such as those based on Arduino-like programmable platforms), or to use different types devices that are already preset to collect and store the data locally, which has lower development costs but are limited in terms of types of collected data (e.g., accelerometer sensors are not commonly present in GPS receivers). Contrarily, smartphone development is more intricate as there are different operating systems one can target (e.g., Android, iOS) and the development is limited by the operating system's capabilities. While previous research documented parts of the difficulties of developing background services for data collection (Singhal & Shukla 2012, Prelipcean et al. 2014), there is no research that documents how apps are distributed to users, which is concerning as some distribution methods come with high security risks (Shabtai et al. 2009). Different alternatives for distributing smartphone apps are discussed in Section 4.2.

Table 3. A comparison between the most common implementations of memory-based declaration, automated and semi-automated travel diary generation methods.

	Memory-based (web form)	Automated (dedicated)	Semi-automated (smartphone)
Design	Web form with questions	Not necessary	Design for annotation and data collection
Distribution	Cheap	Expensive	No cost
Fill-in	Answer questions	N/A	Enhanced by self-learning classifiers
Retrieval	Cheap	Expensive	N/A
Analysis	Data already centralised	Data have to be centralised	Data already centralised

Besides the differences in distribution and development required for either option, these methods are similar. However, there are two main issues with automated travel diary generation. First, while there is continuous research on segmenting trajectories into trips and triplets (Zheng et al. 2008, Stenneth et al. 2012, Biljecki et al. 2013, Rasmussen et al. 2013, Prelipcean et al. 2016, Safi et al. 2016), inferring purpose (Wolf et al. 2001, Griffin & Huang 2005, Lu et al. 2013, Xiao et al. 2016, Ermagun et al. 2017), destination (Ashbrook & Starner 2003, Trépanier et al. 2007, Alvarez-Garcia et al. 2010, Nassir et al. 2015) and travel mode (Gonzalez et al. 2010, Gong et al. 2012, Prelipcean et al. 2014, 2017b, Shafique & Hato 2016, Su et al. 2016, Mäenpää et al. 2017), there is a relatively limited body of research dedicated to fully automating the generation of travel diaries from raw data (Wolf 2000). Second, the automated generation of travel diaries is accompanied by a lack of ground truth data. These two downsides make it difficult to compare, assess and decide whether automation of travel diaries is feasible as a standalone travel diary collection method.

2.2.3. Semi-automated travel diary generation

The semi-automated travel diary generation is a compromise solution between automated travel diary generation and the memory-based declaration of travel diaries (as shown in Table 3). Semi-automated travel diary generation uses similar methods to collect and annotate raw data into travel diaries as automated travel diary generation systems, and users are asked to confirm or change their inferred travel diaries. The main advantage of semi-automated travel diary generation is that they are more likely to obtain ground truth data since users validate their travel diaries, and this method does not overburden users by requiring them to answer questions, but rather to correct attempted answers. As such, one can see semi-automated travel diary collection systems as suggestion enhanced surveys where a classifier attempts to infer the travel diaries for users and learns from the users' corrections.

While the semi-automated travel diary generation seems similar to having an automated generation of travel diaries with an interface, there are two technical details that make them different:

1. the urgency of sending the collected data to a central server (since users need to have access as soon as possible to their travel diaries so they confirm / correct recent trips), and
2. the subset of classifiers that are used for annotating data have to take into account the corrections of the users (change to iterative learning).

The first detail of periodically sending data to a server makes smartphone-based collections more suitable than most dedicated device collections for the reasons specified in the previous section.

The second detail is due to the fact that users can correct inferred travel diaries at will and the classifiers should make use of the newly available training data, which makes most batch learning processes unsuitable for this process. While one can retrain a classifier with the whole history of annotated data any time a user corrects an inferred travel diary, this is a process that has poor performance and other methods such as iterative and online machine learning have proven to be more efficient (Lughofer 2012, Venkatesan & Er 2016). One important problem to raise regarding this difference is that most research in travel diary automation has focused on batch history learning as opposed to iterative and online learning, which has also led researchers to use insufficient performance measures for segmentation and inferences (Prelipcean et al. 2016). The semi-automatic travel diary generation also

changes the traditional sequence of the five steps presented in Section 2.1 to a more cyclical process where the steps are part of improvement cycles. As such, the interface can be deployed multiple times without affecting the collection of raw data and, if performed on web sites instead of smartphones, without needing a redistribution of the smartphone apps.

Similarly, the fill in procedure now benefits from the output of the data analysis step, which requires faster cycles of data retrieval, but allows for a direct improvement in the fill in procedure whenever the classifiers in the analysis step are retrained or improved. This architecture also allows for a faster convergence of a continuously improving semi-automated travel diary generation to satisfy the users' needs (e.g. sufficiently accurate inferences can lead to a decrease in the user annotation burden) since most processes can be measured by using procedures such as A/B testing or blue-green deployments, which are techniques used for comparing different versions of a system / application (Humble & Farley 2010). This also allows for deciding on whether one needs the validation of the users for all generated travel diary entities or only need user confirmation / correction for those that were generated with insufficient accuracy / data support. Once enough data has been annotated and the classifier(s) consistently obtains high accuracy in the classification, these methods converge towards the automated travel diary generation as long as the collected data maintains a similar distribution and characteristics as the already annotated dataset.

In summary, the implementation of semi-automated generation of travel diaries is a system that allows for the collection of travel diaries for a long period of time for a large group of individuals. It is important to note that while these new systems allow for an extended collection of travel diaries as well as other auxiliary data, they are accompanied by a multitude of new problems such as the dependence on users starting collecting data and keeping users interested in annotating their data for the desired time period. These methods can enable researchers to collect travel diaries in a more cost effective way, on a larger scale, and in new regions where travel diaries have not been collected before. However, the only existing such systems are prototypes that have only been used in a limited number of research projects.

3. Examples of automated and semi-automated travel diary collection systems

The main travel diary collection systems are the Georgia Tech Electric Travel Diary (Guensler & Wolf 1999), which is also a programming language used for dedicated devices, the GeoMate (Draijer et al. 2000), the Geologger (Wolf 2000), Sensloc (Kim et al. 2010), Future Mobility Survey (Cottrill et al. 2013), MEILI (Prelipcean et al. 2014), SmartMo (Berger & Platzer 2015), Move Smarter (Geurs et al. 2015), Peacox (Montini et al. 2015), GoEco (Bucher et al. 2016), Modalyzer (modalyzer n.d.), SenseDAT (Sense.DAT - DAT.Mobility n.d.) and TRavelVU (TRavelVU n.d.). Table 4 presents an overview of the technical specifications of these travel diary collection systems and Table 5 presents the segmentation, inference and data collection capabilities of the travel diary collection systems.

An interesting aspect is that while the smartphone-based solutions span from 2010 to the present, these systems have been developed internally or as cooperation with industrial partners, but ultimately without revealing any implementation details since only one system is available with an open source license and without any data restriction, i.e., MEILI (Prelipcean et al. 2014, 2018), at the moment of this writing, based on the authors' knowledge. The lack of transparency on the implementation details as well as the high cost of implementing a system based on a published architecture of a prototype makes the exchange of knowledge in this branch of science difficult and so far insignificant.

Considering Table 4 and Table 5, it is clear that most of the travel diary collection systems developed after 2010 (starting with Sensloc) do not have any major differences between them from a system perspective since most perform trip and tripleg segmentation and they infer travel modes, purposes and destinations. While different systems can use different methods for the inferences or for the segmentation, researchers should not be required to develop a new system or to pay for existing systems (with money or data) every time a new segmentation or inference method is studied or every time a case study is performed. In an effort to minimize the amount of work that goes on building prototypes that already exists, the authors have proposed, implemented and released MEILI (Prelipcean et al. 2014, Prelipcean 2016), which has all the features of existing travel diary collection systems, it has been used in projects in different countries and it has an open source license without restrictions on the collected data.

Table 4. An overview of the available travel diary collection systems, the type of technical solution (hardware or software), the type of travel diary generation / declaration procedures used, the license of the system and the outlet where users annotate their data.

Name	Solution	Type	License	Annotation
Georgia Tech Electric Travel Diary	Hardware	Declare	Proprietary	Device
GeoMate	Hardware	Declare	Proprietary	Device
Geologger	Hardware	Automate	Proprietary	Device
Sensloc	Software	Automate	Proprietary	Website
Future Mobility Survey	Software	Semi	Proprietary	Website & Smartphone
MEILI	Software	Semi	Open-source	Website
Smartmo	Software	Semi	Proprietary	Smartphone
Move Smarter	Software	Semi	Proprietary	Website
Peacox	Software	Semi	Proprietary	Smartphone
GoEco	Software	Semi	Proprietary	Smartphone
Modalyzer	Software	Semi	Proprietary	Website & Smartphone
SenseDAT	Software	Semi	Proprietary	Smartphone
TRavelVU	Software	Semi	Proprietary	Smartphone

Table 5. An overview of the capabilities of existing travel diary collection systems with regards to segmentation of trajectories into trips and triplets, the inference of travel modes, purposes and destinations, and the set of extra data collection sensors employed besides the GPS receiver. The systems that infer travel modes and trip purposes contain the number of travel modes / purposes they infer within parantheses, and “?” if the schema is not specified.

Name	Segmentation			Inferences		Extra Sensors
	Trip	Triplet	Travel Mode	Trip Purposes	Destination	
Georgia Tech Electric Travel Diary	No	No	No	No	No	N/A
GeoMate	Yes	Yes	No	No	No	FM
Geologger	Yes	Yes	No	Yes (9)	Yes	N/A
Sensloc	Yes	No	No	No	Yes	Wifi + Acc
Future Mobility Survey	Yes	Yes	Yes (?)	Yes (?)	Yes	Wifi + Acc
MEILI	Yes	Yes	Yes (15)	Yes (13)	Yes	GSM + Wifi + Acc
Smartmo	Yes	Yes	No	No	No	N/A
Move Smarter	Yes	Yes	Yes (6)	Yes (?)	Yes	GSM + Wifi + Acc
Peacox	Yes	Yes	Yes (6)	Yes (7)	Yes	Wifi + Acc
GoEco	No	No	Yes (13)	No	No	Acc
Modalyzer	Yes	Yes	Yes (9)	No	No	N/A
SenseDAT	Yes	Yes	Yes (?)	Yes (?)	Yes	N/A
TRavelVU	Yes	Yes	Yes (7)	Yes (?)	Yes	N/A

4. Future improvements in travel diary collection methods

This section covers the possible improvements for different travel diary collection methods, both from a practical/operational perspective as well as a research / theoretical one. Section 4.1 covers future possible research directions for travel diary collection systems and Section 4.2 covers a checklist of items that increase the likelihood of success for case study that involves collecting travel diaries.

4.1. Future research directions

In general, the future research directions for travel diary collection methods concern one of the steps presented in Section 2.1, either by improving the techniques used to accomplish each step or by eliminating the need of performing one of the steps (e.g., the retrieval steps is not relevant for smartphone based collections since data are automatically sent to the server and there is nothing else to recover).

4.1.1. Research directions in survey design

In general, the design of the survey's questionnaire for declarative method or of the interface to a semi-automated system benefits the users of the system. However, as previously specified, there are different user segments for whom particular designs and questionnaire types are more effective, which makes the design of a good interface or a good questionnaire difficult to achieve. Conditions such as visual, mental or physical impairment affect how suitable a declarative travel diary collection medium is. Some of the possible research directions to uniformly collect data across different demographics and conditions would entail investigating the full automation of travel diaries or in implementing differential user interfaces (UI) that adapt the user experience (UX) based on the encountered conditions or demographic segment. It is difficult to achieve full automation that yields representative data since the classifiers will most likely be trained on data annotated by support staff based on subjective observations, which does not capture the reality of the traveler, but rather of its observer. Providing adaptive UI and UX has already shown that it has potential in improving functionality for different disabilities, e.g., wayfinding for visually impaired persons (Loomis et al. 2006), consuming information by visually impaired persons (Sadato et al. 1998), designing fonts for dyslexia (Rello & Baeza-Yates 2013). However, it is worth noting that these efforts need to be a result of an interdisciplinary cooperation (e.g., health, transportation, human computer interaction, etc.) and not merely comparative measurements between sets of observations.

4.1.2. Research directions in distribution and retrieval

Although the distribution and retrieval steps are mostly of a practical concern, it is important to investigate how effective different strategies of device / application distributions (and their recovery) are. Lately, a considerable number of tools that facilitate the distribution of apps have surfaced, which allows data collection applications to be sent out to thousands of users with little effort and without costs. Services such as Fabric's Beta (Beta by Crashlytics n.d.) and TestFlight (TestFlight - Apple Developer n.d.) are also certificated under the EU-US Privacy Shield law (Privacy Shield n.d.), which guarantees compliance to the best practices of collecting, using, sharing, and saving personal information, as decided on by the European Union. The high number of users these distribution methods support (i.e., Beta supports an unlimited number of Android devices and 100 iOS devices, and TestFlight supports 10000 iOS devices) allows for developing smartphone-based collection systems in an iterative fashion, which greatly improves the convergence rate towards stable products.

For the already stable and well developed products whose owners do not see a need for fast iteration, the official application repositories (Google Play for Android devices and App Store for Apple devices) are another promising alternative to offer apps for even larger user groups, i.e., to all users of compatible devices within the geographical areas where the applications are offered.

However, these methods are only suited for smartphone apps, the custom hardware solutions lack this kind of distribution methods, which increases the cost and makes iteration difficult for custom hardware-based solution. A possible research direction can contribute to creating new ways of distributing custom hardware-based solutions that allows for fast iterations, which do not involve retrieving from and sending devices back to users for every update.

4.1.3. Research directions in data analysis

Probably most research efforts in travel diary collection systems and methods are spent on data analysis, with a focus on the segmentation of trajectories into trips and triplets, and the inference of trip's purpose and destination, and triplet's travel modes. However, most of the previous research is difficult to reproduce or use due to the specific

use cases and non-disclosed implementation details of most methods, as well as due the reliance on unreasonable assumptions, e.g., performing travel mode detection on given triplegs without taking into account tripleg segmentation errors – see Prelipcean et al. (2016) for more details.

The authors consider that there is a need for consensus on the used methods for measuring the performance of trajectory segmentation, travel entity inferences, and travel diary collection capabilities of a system. Recent research challenged that the traditional performance metrics are not as useful when used to measure the accuracy of segmentation or inference algorithms because they disregard the sequence of activities and travel modes (Prelipcean et al. 2016). Similarly, the comparison of different travel diary collection systems has to take into account the fact that it is difficult to establish ground truth when the characteristics of travel diaries collected by multiple systems and / or methods differ (Prelipcean et al. 2015). To obtain a consensus, it is imperative for the scientific community to decide on a minimum set of attributes that are relevant for measuring how two travel diary collection systems compare with one another. These attributes should capture the most important quantitative and qualitative aspects of travel diary entities (i.e., trips and triplegs). By using these attributes and measures, it should be clearer what are the strengths and weaknesses of each travel diary collection system and / or method, which would also make it easier for researchers to decide on which method to use to collect travel diaries.

Finally, having a benchmark dataset of GPS trajectories (and auxiliary data) and the travel diaries derived from them (which include trips and their destination and purpose, and triplegs and their travel mode) together with the aforementioned accepted performance measures can facilitate the comparison of different segmentation / inference methods.

4.2. Practical checklist for the deployment of travel diary collection systems

This is a practical checklist of the steps to take to increase the likelihood of a successful trial. These steps are based on the authors' experience of successful and failed deployments of production-ready systems and travel diary collection case studies with MEILI. For further information on research projects performed with the help of MEILI, the reader is directed towards Prelipcean et al. (2014, 2015, 2016, 2017a,b), Prelipcean (2016), Susilo et al. (2016), Allström et al. (2016), Allström et al. (2017). MEILI has been used for collecting travel diaries in Stockholm, Sweden for three case studies (171 users in November 2015, 42 users in September 2014, 11 users in November 2013), in Gothenburg, Sweden for one case study (60 users in November 2016) and is currently being used in various international research projects.

There are three main stages to consider when deploying travel diary collection systems: Alfa, Beta and Case study, which are discussed in the next subsections.

4.2.1. Alfa stage - process ownership

The main purpose of the Alfa stage is to form a team that can understand and improve the collection system, to decide on recovery strategies for potential points of failure, and to validate the data collection strategy. The main steps are:

1. Form a technical team, whose role is to understand the main components and functionality of the used travel diary collection system well enough to modify and fix, and to choose the environment for the system to be deployed (if the system is self-hosted).
2. Validate the data collection on a small set of users that can accept mistakes and provide useful and critical feedback on the state of the system from a user perspective.
3. Validate the data collection on the considered devices (e.g., different types of smartphones and smartphone OSes) to prevent regressions due to operating system updates and hardware changes.
4. Identify points of failure and document recovery strategies for each point of failure, which are available for everybody in the team.
5. Perform a simplified version of the analysis intended for the data collected from the final case study to validate that all the data that are needed for the analysis are collected and / or available.
6. Decide on what data to keep logs on (e.g., latency, errors, API response times, etc.) that acts as an indicator of the system's health.

4.2.2. Beta stage - a pilot test

The main purpose of the Beta stage is to perform a simplified version of the final case study with real users to check that the system functions correctly and validate the recovery strategies decided on previously.

1. Organize a pilot test with approximately 10% of the number of users aimed for in the main case study, for a similar period of time as in the case study, in order to validate that the employed collection strategy is valid for a subset of the users.
2. Reiterate through the recovery strategies developed in the Alfa stage.
3. Improve the on-boarding process based on user feedback and relevant metrics, e.g., the time it takes for the users to validate the first travel diary, time it takes the user to log in for the first time.
4. Set up alarms for critical values such high RAM usage, connection pool saturation, disk usage, etc.

4.2.3. Final Stage - Case study

The steps taken during the Alfa and Beta stages should have revealed and solved most issues that could occur during the final case study, and the focus of this stage is on providing user support and checking the system health.

1. Make the recovery strategies easily available.
2. Employ user support to aid users if needed (e.g., email or phone support).
3. The technical team should be available to intervene for unexpected issues, and it is not recommended to develop new features done during the final case study.
4. Gradually invite users in small batches (around 50 at a time) to make sure that the process of registration and first time login is not interrupted.

It is important to note that the knowledge gained while performing these steps is exchangeable and most technical competences are relevant for future case studies, e.g., the technical team does not have to re-learn the process for new case studies.

5. Conclusion

This paper provided a thorough discussion and comparison in between the main strategies for collecting travel diaries, with regards to the general five step process used when organizing case studies that involve the collection of travel diaries. One of the concerns of the authors is the amount of repetition in existing research in travel diary collection systems, which is mostly due to close-source development or a disregard of licensing for the developed systems.

Different methods to collect travel diaries are accompanied by their pros and cons, but in summary, there is no method to collect travel diaries that is valid for all demographics. This suggests that different travel diary collection methods should be complemented with one another, as well as that most travel and behavioural models that are derived from travel diaries collected via only one method are most likely biased and / or incomplete. The paper also provides future research directions that will hopefully allow for a convergence to methods that can collect travel diaries for all demographics, but the infancy of existing research and the efforts needed to consider all demographic groups puts these improvements in the long term research horizon.

Finally, the paper provides a practical checklist to aid researchers to organise case studies that involve the collection of travel diaries. The checklist is generated based on the authors' experience with travel diary surveys and case studies and is meant to raise awareness of difficulties that can be encountered while collecting travel surveys with automated and semi-automated systems, and how to overcome them.

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