



Bluetooth tracking of humans in an indoor environment: An application to shopping mall visits



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ARTICLE INFO

Article history:

Received 19 April 2016

Received in revised form

24 October 2016

Accepted 28 November 2016

Available online 5 December 2016

Keywords:

Bluetooth tracking

Marketing

Indoor

Experiment

Spatio-temporal analysis

ABSTRACT

Intelligence about the spatio-temporal behaviour of individuals is valuable in many settings. Generating tracking data is a necessity for this analysis and requires an appropriate methodology. In this study, the applicability of Bluetooth tracking in an indoor setting is investigated. A wide variety of applications can benefit from indoor Bluetooth tracking. This paper examines the value of the method in a marketing application. A Belgian shopping mall served as a real-life test setting for the methodology. A total of 56 Bluetooth scanners registered 18,943 unique MAC addresses during a 19-day period. The results indicate that Bluetooth tracking is a sound approach for capturing tracking data, which can be used to map and analyse the spatio-temporal behaviour of individuals. The methodology also provides a more efficient and more accurate way of obtaining a variety of relevant metrics in the field of consumer behaviour research. Bluetooth tracking can be implemented as a new and cost effective practice for marketing research, that provides fast and accurate results and insights. We conclude that Bluetooth tracking is a viable approach, but that certain technological and practical aspects need to be considered when applying Bluetooth tracking in new cases.

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1. Introduction

Collecting data to develop insights into the spatio-temporal behaviour of individuals can be of interest for many domains. Crowd management, safety management, operational research and consumer research in marketing provide examples of such domains (e.g. Yamin and Ades (2009)). The specific application discussed in this paper is situated in the domain of marketing research. However, the methodology itself is not limited to this domain and many insights from this specific case can be extended to other applications. We present the case of a Belgian shopping mall that wants to track customers in order to obtain insight into their behaviour. The traditional approach is periodically (e.g. every six months) hiring market research firms that survey random customers of the shopping mall about their shopping trip. Information collected this way inherently suffers from various drawbacks, such as inaccurately

reported information and sample bias (Andres, 2012). Tracking methods overcome many of the disadvantages that characterize the more traditional methods. Actual paths, exact time measurement and other high quality statistics can be obtained. Still, surveys have some advantages that cannot be ignored, such as the possibility to gather more in-depth information about certain consumer preferences and characteristics (e.g. age, gender). Depending on the desired kind of information and the available budget, an adequate combination of both methods can be used.

Tracking individuals requires some form of identification. Previous research mainly used Radio Frequency Identification (RFID) technology for this purpose (Fujino et al., 2014; Hurjui, Graur, & Turcu, 2008; Kanda et al., 2007; Liao & Lin, 2007; Takai & Yada, 2010). However, unlike Bluetooth tracking, this methodology suffers from various specific drawbacks (see Section 2.2.3). This research is to our knowledge one of the first applications of Bluetooth tracking in a real-life indoor retail setting. The real-life use-case examines and demonstrates the value and possibilities of the method. The findings have implications that go beyond the specific setting of a shopping mall.

In the remainder we discuss the application of Bluetooth

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technology with the purpose of tracking humans in an indoor environment. In Section 2 we review literature concerning tracking in general. We also discuss the use of Bluetooth for positioning purposes and touch upon developments in indoor positioning in general. Section 3 discusses the design of the study, along with some important preceding test cases that were used to optimize the methodology. The results are reported in Section 4. Section 5 summarizes the main findings, while we discuss some limitations and suggestions for further research in Section 6.

2. Literature review

2.1. Customer tracking

Researchers have studied the movement of people in different contexts and on various scales. Specifically for marketers, tracking data provides valuable information. Larson, Bradlow, and Fader (2005) state that a better understanding of the shopping process could lead to important discoveries for retailing. Knowledge about in-store customer behaviour by means of path tracking is beneficial for improving Customer Relationship Management (CRM) and streamlining store operations (Celikkan et al., 2011; Vukovic, Lovrek, & Kraljevic, 2012). Already in 1966, it was clear that store layout impacts shopping behaviour (Farley & Ring, 1966). Sorensen (2003) provides an illustrative example by demonstrating that a store entrance on the right side generates an average boost in sales of two dollars per customer. This placement of the entrance favours counter-clockwise movement in the store, which apparently leads to higher sales. Knowledge about customer trajectories is a treasured input for the process of optimizing store configuration. Observing customers by means of tracking their path makes it possible to position products and stores in a way that increases sales and for example draws customer attention to previously less attracting parts of the store (Vukovic et al., 2012). Customer tracking unveils information about what sections people like, dead spots and favourite recurring spots. It can also be used to better estimate and improve many key performance indicators in the field of marketing. The fact that there is a market for these ideas is illustrated by the establishment of companies that deliver exactly these insights to their customers. Examples are Senion (Senion, 2016), Crosscan (Crosscan, 2016) and Bluenion (Bluenion, 2016). These companies mainly use Bluetooth and Wi-Fi signals. More about these technologies in the context of tracking can be found in the next Section (2.2). Apple's Bluetooth based iBeacon is another player in this market (Apple, 2016a). iBeacon is frequently used for push marketing applications, where customers get notifications when they are close to such beacon. Nevertheless, this technology could also be used for tracking and positioning purposes. However, this requires the installation of an application by users. An important advantage of the method discussed in this research is that it does not require this.

Tracking humans is technologically challenging. Research therefore commonly makes use of proxies. These are devices or objects that can be tracked more easily and are therefore used as an approximation of the location of the user. Shopping carts are a commonly used proxy for the movement of customers (Celikkan et al., 2011; Larson et al., 2005; Sorensen, 2003). In this case, the shopping cart is equipped with an RFID-tag in order to enable localisation. The dependence on a shopping cart however limits the generalisability of the method. We therefore suggest mobile phones as a more suitable proxy, since almost every individual carries it along at all times. Also, a mobile phone is typically linked to one individual only and people typically have it in their pocket, meaning that the location of the phone very closely follows the location of the individual.

2.2. Methods for tracking

Traditionally, researchers and practitioners had to rely on methods such as shadowing (Millonig & Gartner, 2008, pp. 1–14; Quinlan, 2008), collecting travel diaries (Axhausen, Zimmermann, Schönfelder, Rindsfuser, & Haupt, 2002) and surveys. These methods can provide rich information, but are very labour intensive. Liebig and Wagoum (2012) state that surveys are the most common method for gathering customer information, but that the high cost and the low representativeness due to the non-random sampling process strongly deteriorates its practical value. Another method that is used to track customers is the use of light curtains. A light curtain consists of two poles and is usually found at the entrance of a store. When a customer passes through the light curtain, the invisible light beam is interrupted and the visit of a customer is registered. This method is very limited, since it cannot uniquely identify customers and is therefore basically limited to visitor counts. It is impossible to construct paths, nor is it possible to calculate duration of stay or to obtain information about return behaviour. Video tracking is another approach for gathering information about customer behaviour. Saxena, Brémont, Thonnat, and Ma (2008) argue that the use of video data to track individual movements forms a challenging task. The need for manually filtering out the information renders this method too labour intensive (Versichele, 2014), whereas computer vision-based alternatives need to make use of advanced image processing algorithms that may not always be a straightforward option (Celikkan et al., 2011). The most valuable methods for tracking are based on wireless signals. In the remainder of this section we discuss GPS, RFID, Bluetooth and Wi-Fi.

2.2.1. GPS

Being explicitly designed for positioning purposes, GPS possesses interesting characteristics such as high accuracy. Unfortunately, there is no GPS coverage in an indoor environment. To overcome this issue, GPS repeaters have been developed. An outdoor GPS antenna, generally installed on the roof of a building, is connected to an indoor antenna which re-transmits the signal. Nonetheless, this solution is not sufficient in the case of tracking customers. The re-transmitted signal is limited to the location of the outdoor antenna and this would imply installing multiple, expensive repeaters per location of interest. Furthermore, this method is not applicable in a multi-level building, such as a shopping mall. Locata is another proposed solution to the indoor limitations of GPS. This local positioning system emits signals that are equivalent to GPS signals for the receiving device (Rizos, Roberts, Barnes, & Gambale, 2010). The system is however quite expensive. It is also more aimed at indoor positioning, not so much at tracking (see also 2.3 Indoor Positioning).

2.2.2. RFID

Several researchers used Radio Frequency Identification (RFID) as a technology for tracking humans (Fujino et al., 2014; Hurjui et al., 2008; Kanda et al., 2007; Liao & Lin, 2007; Takai & Yada, 2010). Due to its high positional accuracy and its applicability in indoor settings, RFID promises to be a valuable option for tracking customers in a marketing context. The methodology is however limited due to the fact that people do not simply carry an RFID-tag along. Therefore, researchers have equipped shopping carts with RFID-tags (Jung & Kwon, 2011; Larson et al., 2005; Nakahara, Uno, & Yada, 2010; Sorensen, 2003; Vukovic et al., 2012). The advantage is that a high percentage of shoppers will be tracked. This approach however strongly limits the generalisability of the method to settings where shopping carts (or similar proxies, cf. 2.1) are available. In addition, the sample of tracked customers might be biased, since

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