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Assessment of antenna characteristic effects on pedestrian and cyclists travel-time estimation based on Bluetooth and WiFi MAC addresses

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ABSTRACT

Monitoring pedestrian and cyclists movement is an important area of research in transport, crowd safety, urban design and human behaviour assessment areas. Media Access Control (MAC) address data has been recently used as potential information for extracting features from people's movement. MAC addresses are unique identifiers of WiFi and Bluetooth wireless technologies in smart electronics devices such as mobile phones, laptops and tablets. The unique number of each WiFi and Bluetooth MAC address can be captured and stored by MAC address scanners. MAC addresses data in fact allows for unannounced, non-participatory, and tracking of people. The use of MAC data for tracking people has been focused recently for applying in mass events, shopping centres, airports, train stations, etc. In terms of travel time estimation, setting up a scanner with a big value of antenna's gain is usually recommended for highways and main roads to track vehicle's movements, whereas big gains can have some drawbacks in case of pedestrian and cyclists. Pedestrian and cyclists mainly move in built distinctions and city pathways where there is significant noises from other fixed WiFi and Bluetooth. Big antenna's gains will cover wide areas that results in scanning more samples from pedestrians and cyclists' MAC device. However, anomalies (such fixed devices) may be captured that increase the complexity and processing time of data analysis. On the other hand, small gain antennas will have lesser anomalies in the data but at the cost of lower overall sample size of pedestrian and cyclist's data. This paper studies the effect of antenna characteristics on MAC address data in terms of travel-time estimation for pedestrians and cyclists. The results of the empirical case study compare the effects of small and big antenna gains in order to suggest optimal set up for increasing the accuracy of pedestrians and cyclists' travel-time estimation.

1. Introduction

Studying spatio-temporal movement of human has been recently focused especially in terms of crowd congestion control, safety, public transport and movement behaviour assessment. Various movement sensors have been developed by robust passive and active positioning technologies for capturing human's movement dynamics. The analysis of people movement's

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dynamic has received attention particularly in the field of visual analytics (Andrienko and Andrienko, 2007a). The study of big volumes of trajectory information of objects moving through geographical space has become a major subject of notice in research fields such as geographical information science (Ahlqvist et al., 2010; Shaw et al., 2008), computer science (Bogorny et al., 2009), urban evacuation (Nassir et al., 2013, 2014), visual analytics (Andrienko and Andrienko, 2007b) and urbanism (Van Schaick and Van der Spek, 2008). However, the greater part of research has been applied to people mobility in different contexts and at various scales. For instance, the movement of athletes on a pitch (Laube et al., 2005), tourists on a regional (Ahas et al., 2008) and local scale (Kemperman et al., 2009; O'Connor et al., 2005; Shoval and Isaacson, 2007), and customers in a supermarket (Hui et al., 2009).

Interests in dynamic movement modelling of pedestrians and cyclists are increasing because of the pressure of urban growth on city infrastructure (Bierlaire and Robin, 2009; Duives et al., 2013; Kasemsuppakorn and Karimi, 2013; Kneidl et al., 2013; Weidmann et al., 2014). This has increased the demand for developing information and simulation tools in order to design new urban infrastructures as well as improvement of current urban foundations. Capturing movement data from pedestrians and cyclists plays a key role to model their travel behaviour and habits especially for enhancement of urban transport systems. While various range of information acquisition methods have been introduced, each method is associated to noticeable issues such as precision, privacy, and maintenance costs.

Surveys and video processing have been used as popular methods for recording information from people. Traditional survey has its limitations to the sample size, non-random sampling and excessive cost. Advanced video surveillance has a better capture rate but it's automatic data acquisition is highly sensitive to the weather conditions, viewing angles, illumination changes, density and brightness of crowd (Liebig and Wagoum, 2012). Video processing also requires considerable process time and complex algorithms in order to reconstruct individual movements across multiple camera angles. These drawbacks restricts video surveillance methods to capture the spatio-temporal paths of only limited objects in few spatial spaces (Dee and Velastin, 2008). Positioning the cell-phones based on Global System for Mobile (GSM) communication has also been explored to monitor people's movements. However, it has become less applicable especially due to the privacy objection concerns and large error range (for civilian use) (Giannotti and Pedreschi, 2008).

In response to the mentioned issues and given the ubiquity of WiFi and Bluetooth-enabled devices such as smart phones and tablets carried around by their owners, WiFi and Bluetooth technologies have increasingly attracted significant attention as a low-cost alternative for the reconstruction of spatial behaviour (Bullock et al., 2010; Wasson et al., 2008; Versichele et al., 2010; Mottram, 2007; Van LonderseLe et al., 2009) for various applications such as direct measurement of pedestrian and cyclist's travel time (Malinovskiy et al., 2012), space utilisation behaviour (Abedi et al., 2014) and location's popularity evaluation (Vu et al., 2010). Also, tracking individual in this method remains anonymous avoiding potential privacy infringements because each fixed Media Access Control (MAC) address cannot be associated to any personal information such as names or mobile numbers. Bluetooth and WiFi MAC address data are also increasingly being used for road traffic monitoring and management (Tsubota et al., 2011; Nantes et al., 2014; Bhaskar et al., 2014a,b, 2015; Abbott-Jard et al., 2013). However, the major weakness of MAC address data is that its sample size may not represent the real sample number because there is the possibility of carrying more than one active WiFi and Bluetooth devices by a traveller and not all travellers will be carrying active WiFi and Bluetooth devices.

Antenna characteristic is a physical element that significantly impacts on the data range and accuracy of MAC address based movement tracking. Basically, higher gains of antenna provide wider scanning ranges. For travel-time estimation applications, setting up MAC address scanners equipped to an antenna with big gain is usually suggested for highways and main roads to track vehicle's movements. However, limited research has been done in order to offer optimal gain of antenna for travel-time estimation of pedestrians and cyclists. Pedestrian and cyclists mainly move in built-up districts and city pathways where plenty of fixed WiFi and Bluetooth devices may operate. Unlike vehicle transportation, people may travel in smaller scales with various speeds as a walker, runner or cyclist. Hence, the size of scanning area can significantly impact on the data range and capturing accuracy. This paper aims to investigate the effects of antenna's gain on the accuracy of collecting movement data from pedestrians and cyclists.

This study evaluates the results of different gains of antenna to the real-data in order to suggest an optimal set up for enhancing the performance and accuracy of MAC address data in terms of pedestrians and cyclists travel-time estimation. A case study based on experimental tests and scenarios has been carried out over a bridge allocated only to pedestrian and cyclists. The result of this study evaluates the advantages and drawbacks of antenna's gains in terms of capturing more relevant and less anomaly samples. The results of this research can be applied in the application of pedestrians and cyclists travel-time estimation for optimal and efficient data collection, decreasing processing time and enhancing tracking accuracy.

The rest of the paper is structured as follows. Section 2 first presents the recent studies done on the analysis of human's movement behaviour and thereafter outlines the MAC address dataset as a technology for tracking people's movement. Section 3 describes the details of the experiment and pre-processing on the data. Section 4 presents the results of the analysis performed on the case study. Finally, the paper is concludes with the discussion on the importance of antenna characteristics on the accuracy of MAC address data set.