Crowdsourcing (in) Voluntary Citizen Geospatial Data from Google Android Smartphones

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Abstract: By 2016 it is projected that there will be over 2 billion smartphone users worldwide with Google's Android operating system installed on the vast majority of these devices (82.8% market share as of Q2 2015). The majority of Android smartphones sold in the last three years have GPS functionality and, unless actively disabled by the user, have a Location History feature that records the phone's geographic coordinates at frequent intervals whenever the phone is powered on. User interaction with the device or an active display is not required for the recording of these data and as such users may be unaware of the data being collected. Google has introduced Google Maps Timeline that facilitates mapping and interacting with a user location history data via Google Maps, and also provides a service called Takeout with the explicit goal of facilitating user access to personal data held by Google, including Location History. The Location History data can be downloaded and analysed using GIS software, representing a potential step-change in Volunteered Geographic Information (VGI). This potential collective repository of geospatial data represents a key emerging geodesign technology for geographers, landscape architects and planners – if researchers and practitioners can access it. In this paper we discuss preliminary results of a research project that piloted a technique for collecting crowdsourced Google Location History data in the context of a walkability study. We provide an overview of the process and an evaluation of its strengths, limitations and challenges. Our findings indicate that data obtained from Google Location History can be of high quality and capture fine scale processes such as walking, however the quality varies depending on Android settings and decreases without a mobile data plan. We conclude with recommendations for future research and a discussion of optimal approaches for data acquisition.

Keywords: Crowdsourcing, Geodesign, landscape architecture, VGI, walkability

1 Introduction

The advent of Web 2.0 technologies have fundamentally altered how we interact with the Internet, transitioning from a model of consumption to one of participation and collaboration (VOSSEN & HAGEMANN 2007). One of the key features of the Web 2.0 era is an embracing of the Web to "harness collective intelligence" (O'REILLY 2005). One of the most well known examples of Web 2.0 is Wikipedia (https://www.wikipedia.org/), an online encyclopaedia that allows any user to add, edit or update information on any entry to the encyclopaedia, which relies on the Mediawiki software (https://www.mediawiki.org/) for its interactive functionality. In the context of landscape architecture education it has been presented that the mediawiki software can be used to improve group work and teach information literacy (LINDQUIST 2007). In a more explicitly spatial context examples of Web 2.0 projects include Wikimapia (www.wikimapia.org), OpenStreetMap (www.openstreetmap.org) and geotagged photographs in Flickr (https://www.flickr.com/map), which have been collectively referred to by Goodchild (2007) as volunteered geographic information (VGI). While offering great opportunity for expanded data collection VGI is not without its challenges as it is differentiated from conventionally produced forms of geographic information because of "the content of the information, the technologies for acquiring it, issues surrounding its

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quality, the methods and techniques for working with it, and the social processes that mediate its creation and impacts" (ELWOOD, GOODCHILD & SUI 2012). Further, it has been asserted that VGI "represents a dramatic shift in the content, characteristics, and modes of geographic information creation, sharing, dissemination, and use" (ELWOOD et al. 2012). Such citizen driven approaches to data collection are not entirely new, and as pointed out by ELWOOD et al. (2012) can be traced back at least to 1930s Britain when land use surveys were primarily conducted by teachers and school children (STAMP 1931).

As with Web 2.0 technology more broadly there is not much known specifically about why people choose to contribute VGI data. This opens up the phenomena to criticism similar to that which was aimed at Wikipedia early on, with critics citing issues of data accuracy, ulterior motives and lack of expertise of contributors (DENNING, HORNING, PARNAS & WEINSTEIN 2005), though in many cases the concerns were shown to be overblown (MEYER 2006). The specific issue of data quality is a challenge for VGI with a evidence for the varying quality data (NEIS, ZIELSTRA & ZIPF 2013), though promising research indicates that data quality increases with the number of participants (HAKLAY, BASIOUKA, ANTONIOU & ATHER 2010). In addition, three approaches to quality assurance of data have been proposed relying on crowdsourcing, expert moderation and/or comparison of data to existing geographic knowledge (GOODCHILD & LI 2012). Considering VGI in the context of neogeography as presented by Rana and Joliveau (2009) can further contribute to accuracy where it is an extension of mainstream geography with new producers of data collaborating with professionals for analysis, rather than the professional being removed from the process altogether. In this professional-layperson type of collaboration VGI has been used for developing framework data (data describing the location of features, e. g. Open Street Map) as well as non-framework data (e. g. people's recordings of certain conditions, e. g. vernal pools (TULLOCH 2008)).

VGI has important implications and applications specifically in a geodesign, landscape architecture and planning context. Campagna (2014) introduces the concept of Social Media Geographic Information (SMGI) where Spatial-Temporal Textual Analysis (STTx) is used to explore people's spatiotemporal perceptions and interests, with the goal of "integration of experiential and pluralist spatial information with authoritative spatial data sources and sensor-web". When properly facilitated using digital mapping interfaces, VGI has been shown to "provide landscape architects and allied design professionals with local, detailed and spatial information that can be used to create a more informed design solution" (SEEGER 2008). Until recently, obtaining high resolution and personalized mobility data required having subjects carry GPS tracking devices (JERRETT ET AL. 2013; SHOVAL, KWAN, REINAU & HARDER 2014) or install customized smartphone software (PALMER, ESPENSHADE & BARTUMEUS 2013). However, due to the high costs and the specialized information technology skills necessary for these studies, researchers have found them challenging to implement. Also, the generalizability of this early research was compromised due to the limited participation that restricted spatial coverage. VGI has benefited from technological development in recent years, particularly from geolocated photographs and smartphones equipped with GPS. Schmid et al. (2012) describe a method for mapping small geographic areas using a smartphone and its camera. The ubiquity of smartphones presents a key opportunity for collecting VGI and offers a potentially robust method for studying fine scale movement, such as pedestrian mobility.

What separates our research from previous VGI approaches is that we are avoiding the specific issues of participants having ulterior motives or lacking expertise by collecting data that many may not have known was being collected. Our research leverages crowdsourcing personal spatial data from owners of Google Android smartphones, of which the majority sold in the past three years have GPS functionality. Unless the GPS is actively disabled by the user, or the default settings adjusted, Android smartphones have a Location History feature that records the phone's geographic coordinates approximately every minute whenever the phone is powered on. User interaction with the device or an active display are not required for the recording of these data. Google has introduced Google Maps Timeline (https://www.google.com/maps/timeline) that facilitates mapping and interacting with a user location history data via Google Maps, and also provides a service called Takeout (https://www.google.com/settings/takeout) that has the explicit goal of facilitating user access to personal data held by Google, including Location History. The goal of this paper is to report our preliminary findings of the piloted technique for collecting crowdsourced Google Location History data in the context of a walkability study and provide an evaluation of its strengths, limitations and challenges in order to encourage future research.

2 Case Study: The Realized Walkshed

Characterizing the patterns and elements of urban form and their historical evolution has long been a focus in urban planning (BACON 1967, KOSTOF 1991), with detailed investigations revealing how natural and physiographic features, land use, and street layout have shaped the physical forms of cities (SCHWARZ 2010, SONG et al. 2013 WHEELER & BEEBE 2011). Recent research combining urban form and human mobility has indicated that the movements of people in the urban environment are also directly affected by elements of urban form. For example, people tend to walk more when they live in neighbourhoods that are internally well connected by a network of sidewalks. Higher density neighbourhoods invite more walking, as do areas with high quality public spaces, and a wide range of land uses and services. Walkable neighbourhoods support social connections, and decrease the use of passive modes of transportation, such as motorized vehicles. Walkability thus contributes to reduced carbon production, higher real estate valuation and improved public health (ALANIZ URIBE & SANDALACK 2011, GILDERBLOOM, RIGGS, & MEARES 2015, LOPEZ & HYNES 2006).

Urban form – the arrangement of physical elements that make up cities – has been shown to influence quality of life outcomes, and is an active area of interest in urban planning (DEMPSEY 2008, ROGERS, HALSTEAD, GARDNER & CARLSON 2010, SONG et al. 2013). Much research has focused on walkability, or pedestrian mobility within urban areas (FORSYTH, HEARST, OAKES & SCHMITZ 2008, FRANK, ENGELKE & SCHMID 2003, SANDALACK et al. 2013) and has largely measured the structural properties of urban form that can influence walkability, such as street layout (LESLIE et al. 2007, OLIVER et al. 2007, SANDALACK et al. 2013), or relied on self-reported surveys of mobility (FORSYTH et al. 2008, LEE & MOUDON 2008). However, what these research methods miss is the spatial pattern and timing of movement; thus, examining specific elements of urban form and their actual influence on walkability have been limited. We aim to overcome this limitation by leveraging a novel data collection technique of crowdsourcing personal spatial data from owners of Google Android smartphones.

3 Methodology

3.1 Collection of Google Location History

As our research involves human subjects, all aspects of the project received required ethics approval. Participants were university students recruited via email and print advertising directing them to a website (http://walkability.ucalgary.ca/). Each was required to own an Android based smartphone and was requested to donate a twelve-month portion of their personal Location History for this study in exchange for a $25 gift card. Thirty participants were recruited in total during June and July 2015. The procedure involved participants meeting a member of the research team in a university office where they were briefed about the project, provided the opportunity to ask questions, and assisted with downloading their data from the Google Takeout website.

3.2 Realized Walkshed

Realized walksheds were estimated using statistical methods (BENHAMOU & RIOTTE-LAMBERT 2012, DOWNS & HORNER 2009, KENWARD et al. 2001) designed to delineate regions with high densities of points. This ensured walksheds describe areas with the highest probability of use by the participant and are also sensitive to the existence of multiple core areas such as those representing home, workplace, university or habitual recreational activities. Spatial data was first prepared by calculating the travel rate at each location and defining active travel that is pertinent to walksheds – which we classified as movement between 1 and 5 km/h. This rate was selected as most likely to exclude static locations, most bicycle and virtually all sustained motorized travel. We restricted analyses to locations within the City of Calgary and conducted them individual temporal windows so as to capture how walksheds change across seasons and times of day.

4 Results

4.1 Collection of Google Location History

GPS location data suitable for estimating walksheds was successfully collected from 21 of 30 participants while for 9 the data were recorded too infrequently for our purposes. In these cases, discussions with participants indicated that either the GPS receiver or mobile data transmission were de-activated. The Android operating system appears to send location information in real-time to Google servers, and requires both of these phone functions to be activated in order to capture fine-scale movements such as walking. These participants had disabled these features on their phones to conserve battery life or mobile data usage, or had no mobile data plan. Android phones will also estimate geographic location using wireless Internet router (Wi-Fi) telemetry. If this feature is activated and the phone is connected to Wi-Fi networks when estimated, these locations will be recorded in the participant's location history. However, these data are typically too infrequent and too spatially imprecise to capture walking, and rather reflect broad-scale movements during the day (e. g. from a home Wi-Fi network to a workplace network). Figure 1 illustrates the point data collected for all participants restricted to their locations within the City of Calgary.

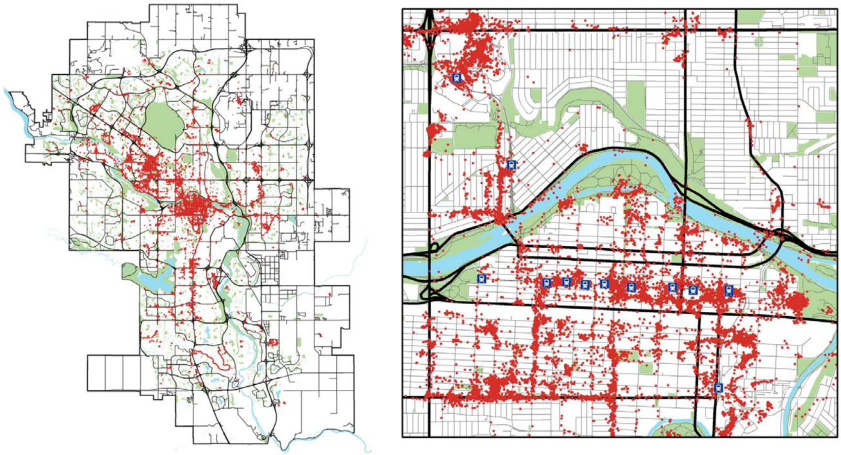

Fig. 1: GPS location data for 30 participants within the City of Calgary (left) and a detailed downtown section

4.2 Realized Walkshed

The preliminary results for realized walksheds for a trial participant are shown in regions with high densities of points (Figure 2; white polygons) which were estimated using a multinuclear core clustering approach (KENWARD et al. 2001). Realized walksheds at home (H) and workplace (W) foci are labelled. Active travel locations are those where the travel rate is between 1 and 5 km/h calculated as the displacement from a location recorded one minute earlier (Figure 2; yellow points). Vehicular travel locations (> 10 km/h) are included for comparison (Figure 2; red points). Here we conducted analysis for a single temporal window (weekday mornings during winter 2014). Changing these parameters will allow us to capture how walksheds change across seasons and times of day, a sample variation of which is shown in Figure 3.

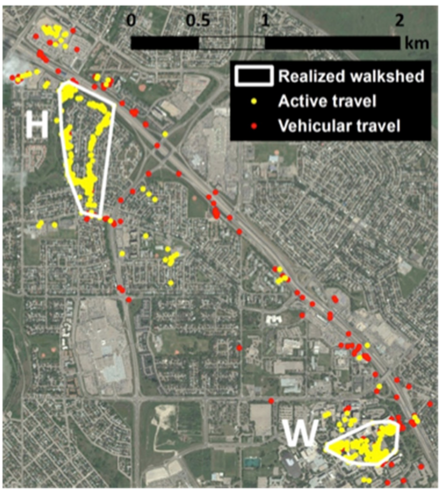

Fig. 2:
Two realized walksheds in Calgary, Canada on weekday mornings during winter 2014, based on Google Android smartphone Location History

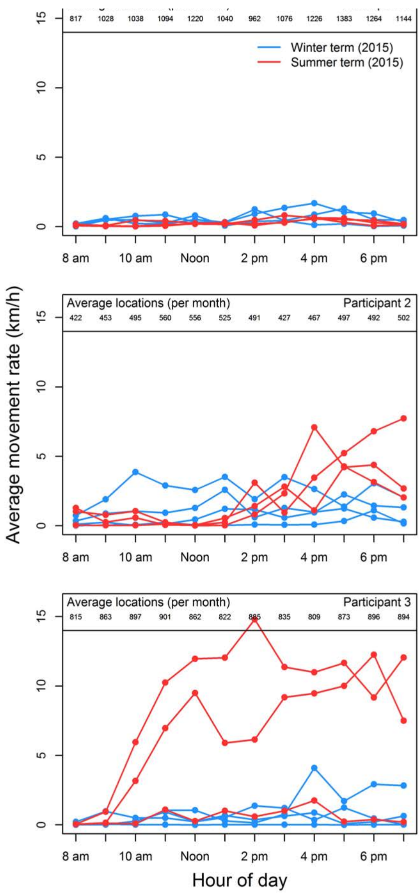

Fig. 3:
A plot for three randomly selected participants showing 2015 average movement rate by month (separate plot lines) and hour of working day. Other hours are omitted because people are generally still during these times and it obscures the interesting parts of the plot. This combines all changes in position (i. e. movement by, car, bus, c-train, and possibly even aircraft as well as walking and still moments). Except for participant three who appears to have been employed as a driver in the summer months of 2015, you can discern commutes, and see large differences in people's travel patterns.

5 Discussion

Initial review of data obtained indicates that participant data quality and its power to capture fine scale processes such as walking varies with how the user configures their Android phone, and the presence of mobile data plan. It is likely that the version of the Android operating system also influences how data are obtained. Future engagements with participants should also include a systematic interview regarding their phone using habits, the type of operating system, the availability of a data plan, the manufacturer and model of the phone, and whether the GPS functionality is usually engaged. Google does not document specific details of their operating system or publish their plans for its development, and as such, researchers relying on these data must be prepared for unanticipated changes in the data collection process when Android is updated both within and between major versions of the software. However Google is likely committed to providing this service in the long-term. Recent improvements in both their takeout mechanism and the ability to review personal location history online are evidence of a significant investment in this technology and could be read as a commitment to improved transparency about their collection of personal data.

6 Future Research

Our ongoing research aims to test which urban form attributes, and which social and physical aspects of the urban landscape have facilitated or inhibited walking by our student participants. For this analysis we apply point-pattern statistical methods originally developed to study animal home ranges (DOWNS & HORNER 2009, KENWARD, CLARKE, HODDER & WALLS 2001) and use GIS-based approaches for modelling the structure and connectivity of the urban landscape (e. g. GALPERN, MANSEAU & FALL 2011, GALPERN & MANSEAU 2013).

A first set of analyses will use these data to examine how the following promote or restrict walking behaviour among our student participants at their home or workplace realized walksheds: street block pattern (e. g. grid, warp-grid, or curvilinear); the mix and distribution of land uses; the availability of services; the population density; the mean area of land parcels and green space; and the proportional coverage of features of the built environment (SANDALACK et al. 2013, SCHWARZ 2010, SONG, GORDON-LARSEN & POPKIN 2013). A second set of analyses will examine the boundaries of realized walksheds to understand how sidewalk connectivity and other specific physical features of the city may influence walking. To do this we will compare *realized* walksheds to regions of potentially high walkability – that is, *potential* walksheds – that we will identify using models that incorporate information about how easy pedestrian travel is within the city. Potential walksheds will be modelled using urban planning methods developed for this purpose, such as road network models (OLIVER, SCHUURMAN & HALL 2007, SANDALACK et al. 2013), along with methods from landscape planning that measure the ease of movement (GALPERN & MANSEAU 2013, ZELLER, MCGARIGAL & WHITELEY 2012). Our comparison of potential and realized walksheds also provides an opportunity to evaluate previous approaches to modelling walkability, and to examine whether measuring actual mobility provides more information than describing the structural patterns of cities.

7 Conclusion and Outlook

Smartphone location data collected frequently and with high spatial precision has the power to reveal confidential and personal information, such as the location of a home, a workplace, or a visit to a hospital emergency department. These data can be highly invasive and smartphone users may not be fully aware of how much they may reveal even to a casual observer. It is critical that researchers recruiting participants make this clear. We suggest that recruitment include provisions to demonstrate how location history can be explored through services Google provides and an explicit discussion of what these data might reveal, before data are retained and recruitment finalized. Researchers also have a duty to store these data in a secure manner. This could include storage on encrypted USB flash drives during the data collection process, or, for analytical purposes, retention in a relational database held behind a firewall. We view sharing the implications of these data as a public service intended to empower users to take ownership of their data and to direct it towards community-oriented goals. Understanding the determinants of walkshed size, or assessing walkability and the effective design of urban form are just two of many applications that are set to place this low-cost method of spatial data collection at the forefront of urban geography, geodesign and evidence-based landscape architecture.

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