Identifying Points of Interest for Elderly in Singapore through Mobile Crowdsensing

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Abstract: This paper introduces a crowdsensing approach to identify the points of interest (POI) among the elderly population in Singapore. We have developed a smartphone application, which passively collects sensors' information (e.g. GPS location) on users' mobile devices. Using such information, we can identify popular regions and places among the elderly that could be useful for city planner in preparation for aging population. Our results demonstrate different check-in patterns of various POI, and the elderly spend nearly 70% of non-home duration around their neighborhood.

1 INTRODUCTION

Elderly population is a key component in any society. In Singapore, the number of citizens aged 65 and above is increasing rapidly. In fact, the resident Old-Age Support Ratio (persons aged 20 – 64 years per elderly aged 65 years and over) has significantly reduced from 9 to 5.7 over the years of 2000 to 2015 respectively (Department of Statistics, 2016). Rising elderly population is a challenge to address since their requirements and interests should be understood in order to provide them a better quality of life. According to (Capella and Greco, 1987), elderly have tendency of travelling around in their leisure time, which leads to the thinking that it is important to identify their preference of places to visit. In order to achieve such information we need to reach the elderly and communicate to gather required information from them. Rather than conducting verbal or written surveys, the more convenient approach is to utilize the ubiquitous nature of smartphones among the elderly as a resource to collect data from heterogeneous sensors available in smartphones. According to study in (Pang et al., 2014), elderly in Singapore have positive attitude towards smartphones and have found them to be useful and entertaining. Hence, a smartphone application based approach has the potential in quantitatively identifying elderly lifestyle. The work presented in this paper, adopts a smartphone based mobile application as the tool to better understand the daily activity of an elderly. Using the smartphone sensor information collected through mobile application, we prove that it is possible to identify the Regions of Interest (ROI) and Points of Interest (POI) of elderly in Singapore.

The remaining sections of this paper are structured as follows. Section 2, discusses the literature review and related work done previously. Next, Section 3 discusses the methodology which is used to collect and analyse data from elderly. Section 4 describes the insights about ROI from the analysed data. Section 5 presents POI extracted from each ROI. Finally, Section 6, concludes the paper with a summary of findings, and possible future work.

2 LITERATURE REVIEW

There has been previous research done to track user locations using mobile applications. Tourist tracking through smartphone location data (Viswanath et al., 2014) has been done in order to identify travel sites of tourists and to rate tourist sites based on user surveys conducted through the mobile application. In the context of smart homes, previous work has been carried out for proactive environment change for elderly (Helal et al., 2003), cloud based real-time activ-

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ity tracking in home (Fahim et al., 2012) which helps to remotely monitor elderly who stay at home (Yassin et al., 2017), and RFID based location tracking (Kim et al., 2013) (Liu et al., 2015). An adaptable interface for smartphones which is customized to the elderly has been developed in (Arab et al., 2013). Helping people with limited mobility (e.g. elderly) by suggesting accessible urban paths using crowdsourced data has been done in (Mirri et al., 2014). A passive information gathering system using mobile terminals such as smartphone applications, emails, and phonecalls, has been done to gather knowledge and experience from elderly and transfer to younger generation (Hiyama et al., 2013). In (Ghiani et al., 2013), a platform has been developed to support elderly to stay active in life in order to improve their healthy living.

To the best of our knowledge, there is no previous work done to identify the ROI and POI of elderly, using smartphone based mobile applications. Our focus is not only for the elderly who stay at home, but also for the elderly who prefer to travel around their neighbourhood or further. Therefore, this paper presents an approach to understand lifestyle of elderly, using the data collected through smartphone applications, and analysing them.

3 METHODOLOGY

A user-friendly smartphone application that runs on Android platform, is designed and developed (SUTDDev, 2015) to collect data from elderly. More than 100 people, the majority aged 50 and above, who reside in Bukit Panjang area of Singapore participated in the study by installing the application on their mobile phones. In this paper, we reported only the data from 50 participants, whose collected data is consistent throughout the study period. There are 3 major stages in the approach of identifying ROI and POI, namely, Mobile Application Development, Elderly Data Collection, and Big Data Analysis.

3.1 Mobile Application Development

The smartphone application, which is used to collect data from participants is an improved version of the application introduced in (Viswanath et al., 2014). The application collects data such as GPS location (including latitude, longitude, and accuracy), activity data from Google API, noise level of the environment, device battery level, and light sensor values. In the process of identifying ROI and POI, in this paper, we utilized only the location related data. In future work, our intention is to utilize all the collected information in order to extract deep insights about user behaviour.

3.2 Elderly Data Collection

The recruitment of target participant group for the study (elderly who use Android smartphones and reside in Bukit Panjang area of Singapore) was done in public locations around Bukit Panjang. All the data were collected for one month of minimum period with the written consent from every participant in the study. Participants' personal identity is used only during registration. The data collection and analysis is done through a unique auto-generated device ID to ensure privacy of the participants. Figure 1 shows the flow of elderly data collection.

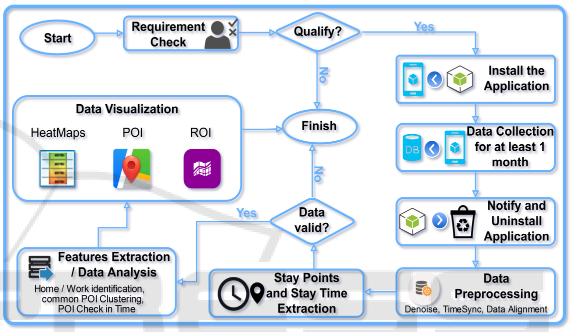


Figure 1: Elderly Data Collection.

3.3 Big Data Analysis

Aquired data from the mobile phones of the elderly need to be analysed in order to gather meaningful insights. Data analysis was done using back-end Java application and MATLAB software package. After the data is analysed, tools such as Google Maps, Voronoi Diagrams, and Heat Maps are used to visualize the gathered insights, so that it is possible to identify the ROI and POI.

Data pre-processing is done in 2 major stages such as (1) Denoise which removes duplicate data records and anomalies occured due to location accuracies, and (2) Time sync which aligns data from different tables in relevant time slots.

After pre-processing stage, the raw location data were clustered using k-means clustering technique (Lau et al., 2017) and generated a summary database for each user, which contains the parameters as shown in Table 1. A total 1781 number of clusters were generated from raw data of all 50 users.

Table 1: Parameters in the summary database.

Parameter	Remarks
ID	Unique user ID
Gender	Male/Female
Age	User's age
Location	Latitude and Longitude of cluster location
Purpose	Purpose of visit (e.g. H-Home, G-Grocery, W-Work)
Duration	Time spent in particular cluster
Visits	Number of visits to particular cluster
Total Time	Duration of first and last record from user

4 REGIONS OF INTEREST

ROI analysis is done in three categories. First, we identify the percentage of home stay duration of each user out of their total participation time. Next we identify the ROI across user neighbourhood, which is Bukit Panjang, Singapore. Further, an analysis is done across Singapore to identify islandwide ROI. ROI are analysed using a technique called Voronoi Diagrams. In a Voronoi diagram, a plane is partitioned into n points such that each polygon contains one seed and every point in each polygon is closer to the seed inside each polygon than to any other one. These polygons are called *Voronoi zones* (Aurenhammer, 1991).

4.1 Home Stay Duration

Figure 2 shows the percentage of time each participant spent at home, out of his/her total participation duration for data collection. It also shows the age and gender of each of the participant. The oldest participant is 75 years old, and the average age for participants is 60 years. There are 28% of male, and 72% of female participants. It can be seen that a large number of participants spend a large amount of their time at home, in particular 44% of participants stayed at their homes for more than 21.6 hours a day on average, 22% of participants stayed at their homes between 19.2 and 21.6 hours a day on average, 8% of participants stayed at their homes between 16.8 and 19.2 hours a day on average, 10% of participants stay at their homes between 14.4 and 16.8 hours a day on average, and 16% of participants stayed at their homes less than 14.4 hours a day on average. It can be noticed that participant IDs 10 and 44, have substantially lower home stay duration, when compared to others. One possible reason for such a result is they switch off their mobile phones at night.

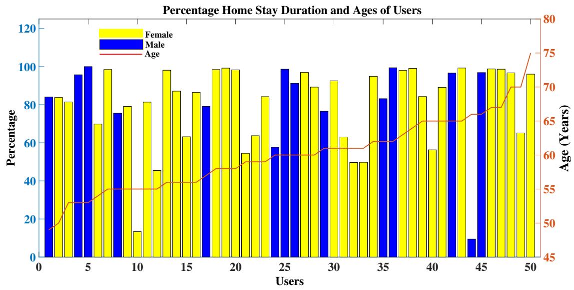
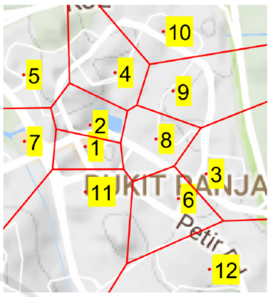


Figure 2: Percentage of home stay duration, gender, and age of each user.

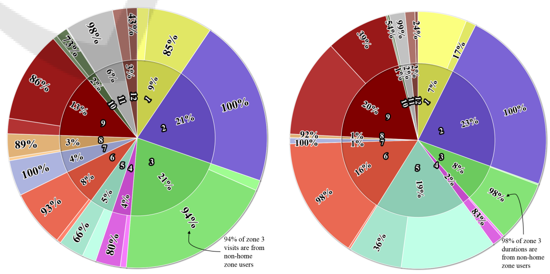


ID	Location	Homes
1	Bukit Panjang Plaza	5
2	Senja Cashew CC	2
3	Masjid Al-Iman	8
4	Greenridge Shopping	2
5	My Family Clinic	5
6	Bukit Panjang CC	4
7	Junction 10	0
8	Zhenghua School	6
9	Fajar Market	5
10	Sheng Siong	2
11	Kimly Seafood	3
12	Michaels' Residence	8

Figure 3: Voronoi zones and the number of participant homes in each Voronoi zone across Bukit Panjang.

4.2 Across Neighbourhood

We divided Bukit Panjang area into 12 Voronoi Zones, in order to get an understanding about participants' home region since all of them are residents of Bukit Panjang. The Voronoi zone distibution, zone number, and number of participant homes in each Voronoi zone is shown in Figure 3.



(a) Percentage of visits. (b) Percentage of durations.

Figure 4: Voronoi zones in Bukig Panjang area and percentages of non-home zone visit and durations.

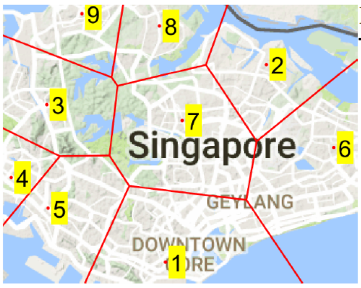
Figure 4a shows the percentage of visits in each region and Figure 4b shows the percentage of durations in each region. In both Figures, the inner circles display the Voronoi zone number and percentage of visits/duration accordingly. The outer rings show the percentages of aforementioned percentages contributed by non-home zone participants.

From the Figures, it can be observed that visits and durations in zone number 2 (Senja Cashew CC) and zone number 7 (Junction 10) have 100% of non-home zone participants, which means, all the participants who visit and spend time in those two zones are residing outside them. Especially, none of the participant homes are located in zone number 7. Zone number 2 also shows the highest percentage duration, while zone number 3 (Masjid Al-Iman) shows the highest percentage of visits.

Another interesting observation is that, zone number 3 has higher percentage of visits when compared to percentage of duration of the same. The reason for such a result is, because the Bangkit LRT station is located inside zone number 3. In terms of percentage duration, zones 2 and 6 are popular among non-home zone participants. Zones 5 and 9 are popular among home zone participants. The reason for such popularity is because those zones include POI such as Bukit Panjang CC (zone 6), Senja Cashew CC (zone 2), and Fajar Market (zone 9).

4.3 Across Singapore

The map of Singapore is divided into 9 Voronoi zones in order to understand what regions across Singapore are in interest of users in terms of number of visits and duration of time spent. The Voronoi seeds are selected to cover the main regions of entire Singapore. The Voronoi zone distibution and zone names are shown in Figure 5.



ID	Region
1	Outram Park
2	Punggol
3	Bukit Panjang
4	Jurong East
5	Clementi
6	Tampines
7	Ang Mo Kio
8	Yishun
9	Woodlands

Figure 5: Voronoi zones across Singapore.

Figure 6 shows the percentage number of visits and durations for each region across Singapore. It can be observed from the Figure that region number 3 (Bukit Panjang) is the most popular among participants, in terms of both visits and duration. In fact, 53.5% of visits and 68.6% of durations belong to that region. The reason for such popularity is because all the participants are residing in Bukit Panjang area and they tend to visit places nearby their homes. Apart from that, regions 1, 4, 5, and 9 are popular regions. However, regions 1 and 9 tend to have shorter duration than visits.

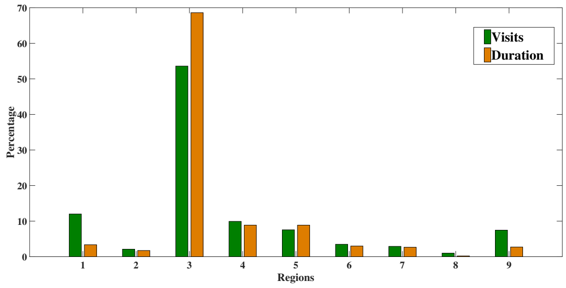


Figure 6: Percentage of number of visits and duration across regions in Singapore.

5 POINTS OF INTEREST

Next, we analyze in deeper details for each specific POI, we have performed POI extraction and ranked it according the number of participant and time stayed. For privacy reason, we have removed participants' home and work places. Later, we have clustered common POI among the participant using density based clustering with radius of 100m (hence the POI indicated later on include also nearby related POI). After clustering process done, we have obtained 980 POIs from the collected data.

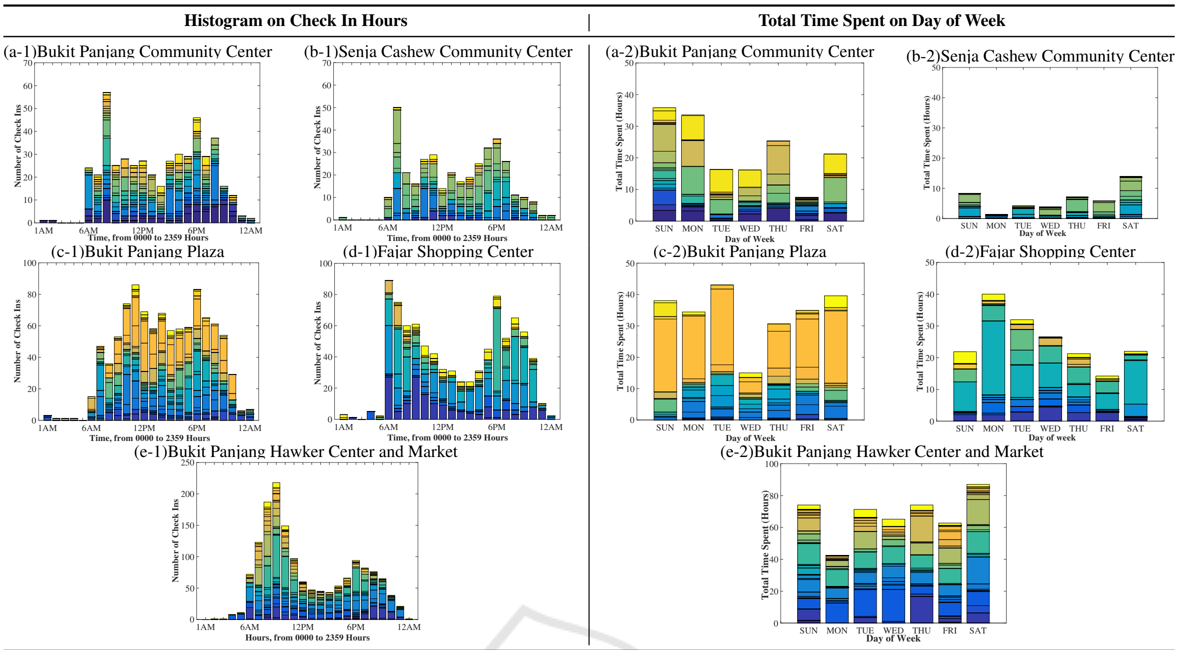
5.1 POI Correlates with Number of Participants and Stay Time

Table 2: POI Ranking based on Number of participants Checked In.

No.	Point of Interest	Percentage of Participants visit	Average Hours Spent Per Participant Per Visit
1	Bukit Panjang Hawker Center	68%	3.7
2	Bukit Panjang Plaza	56%	2.9
3	Bukit Panjang Community Center	34%	1.9
4	Fajar Shopping Centre	30%	2.5
5	Senja Cashew Community Club	28%	4.4
6	Holland Bukit Panjang Town Council	28%	2.2
7	Block 125 Neighborhood Stores	26%	3.0
8	Lot One Shopping Mall	24%	1.7
9	National Healthcare Group Pharmacy - Choa Chu Kang	22%	1.7
10	Chinese Temple at Bencoolen Link	22%	0.9
11	Greenridge Shopping Centre	20%	2.5
12	Ten Mile Junction Mall	20%	2.2
13	Plaza Singapura	18%	2.6
14	Causeway Point	18%	1.6
15	Block 172 Neighborhood Stores	16%	2.4
16	Zheng hua Community Club	16%	2.0
18	Teck Whye Ave Neighborhood Stores	16%	1.3
19	Temple Street at China Town	16%	1.2
20	Phoenix Road Shop Lots	14%	2.6

Orange - Within Bukit Panjang Area, Blue - Within 5KM range of Bukit Panjang, Purple - 5KM away from Bukit Panjang

We have plotted the heat maps for the participants' based on the number of check in across Singapore as displayed in Figure 7. The heat zones are shown in red color, where the yellow color indicates the places, that less participants visited. High heat area are circled and pointed out int the maps, and we do not include



Note:

Fig. 8(a-1), (a-2), (b-1), and (b-2) - Similar Pattern, the difference is time spent on Sunday and Monday.
Fig. 8(c-1) is Gaussian shape histogram, while Fig. 8(c-2) is two peaks histogram; both have one or two fixed participants, who always visit those POI.
Fig. 8(e-1) and (e-2) - morning place, and Monday no market so less, other days balanced

Figure 8: Check In Time and Time Spent for the following POI (*Top to Bottom, Left to Right*): (a) Bukit Panjang Community Center, (b) Senja Cashew Community Center, (c) Bukit Panjang Plaza, (d) Fajar Shopping Center, and (e) Bukit Panjang Hawker Center and Market.

Bukit Panjang Area as it is nearby to the home of participants. We have highlighted a few high heat zone area using circle and labeled it accordingly. We presented in Table 2 the top POI and time spent per visit for the elderly, which the ranking is evaluated based on the number of participants checked in. The POI highlighted in orange indicates the POIs are located within the Bukit Panjang area, where the blue color indicates POI are within the 5 kilometers of the Bukit Panjang area (nearby POI). Lastly, the purple color indicates the POI, that are located outside of Bukit Panjang area.

Based on observation, we noticed the top POI consists of locations from Bukit Panjang area. Hawker center and community center are the most common places among the participants, where at least 1 hour 55 minutes per visit time spent is recorded. Then the ranking followed by the shopping mall and neighbourhood stores. Note that, a high density block (HDB) can be a multi purposes places such as Rank 7, Block 125, which have grocery store and traditional medical center at first storey of the building. So, it is not a uncommon situation in Singapore's highly density new town area development. Participants have spent an average of 2.5 hours in the Bukit Panjang shopping mall area (Bukit Panjang Plaza, Fajar Shopping Centre, Greenridge Shopping Centre, and Ten Milt Junction Mall) per visit.

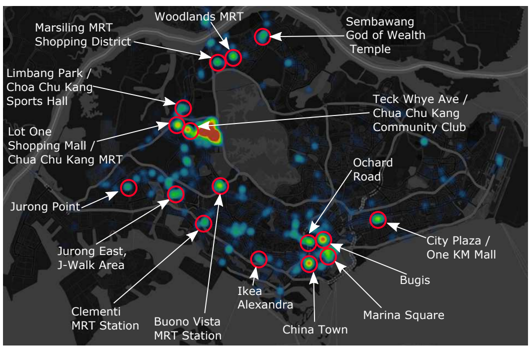


Figure 7: POI heat maps across Singapore.

Next, we discuss the POI, located outside Bukit Panjang area. As shown in Figure 7, there are a handful of location outside of Bukit Panjang area distributed across central area (China Town and Bugis), west south area(Jurong and Clementi), Bukit Panjang nearby area, and north area (Woodlands). A top common area among the elderly is National Healthcare Group Pharmacy, where it is located 2 kilometers away from Bukit Panjang area. Other POI area are mostly shopping malls and temples, which can be related to local cultures and religion.

In a nutshell, participants have the tendency to visit nearby amenities for daily convenience. It can be highly related to the transportation accessibility and travel time. However, when it comes to shopping, religious, and medical purposes, participants are more likely to travel further.

5.2 POI Correlates with Check In Time and Time Spent

After obtaining the POI ranking, we investigate the check in time and time spent for each POI and the results are displayed in Figure 8. We have divided the analyzed data into two categories, which are check in time according to hour of the day and time spent according to the day of the week.

First, we analyzed the top POI from previous section, which are Bukit Panjang Hawker Center and Market. Based on the observation, we can consider it as a morning place, where morning (8am - 10am) have a lot check in compared to other hours. By combining the day spent for different time of the week reveals that Monday have less time spent there compared to other days. The main reason is the operating commercial hour of local market, where Monday is the rest day. By compiling the information collected, it implies Bukit Panjang Hawker Center is a place, where most elderly would go to either secure their grocery or other personal purposes. Note that, participants could have go the Bukit Panjang Hawker Center for different purposes, and we only consider majority purpose collected from the survey.

Next, we discuss about the shopping complex, that majority elderly have checked in during the data collection subsequently after Bukit Panjang Hawker Center. There are two shopping complexs studied here, which are Bukit Panjang Plaza and Fajar Shopping Center. The pattern for both shopping complex is diverse, that for Bukit Panjang Plaza is in Gaussian distribution shape and Fajar Shopping Center is in two peaks shape. It shows checked in time might highly correlate with the location of the shopping mall. For example, Bukit Panjang Plaza is Mass Rapid Transit interchange, which is presumably have more checked in compared to Fajar Shopping Center. We noticed one or two participants that frequently spend their time there and contribute a lot of hours.

Another common POI for the participants would be community center. It is observed that both Bukit Panjang and Senja Cashew Community center have similar check in patterns, where morning and evening are the high checked in time for the elderly. However, by comparing the number of hours spent for in a week, there is a significant variance between Bukit Panjang Community center and Senja Cashew Community club. Bukit Panjang Community center has more check in in Monday and Sunday and we believe the reason could be linked with the activity a community center offered and transportation accessibility to reach there.

In conclusion, we noticed participants are likely to go to Bukit Panjang Hawker Center and Community Center in the morning. Such pattern can be different subject to commercial operating hours and activities offered. However, contrast to community center and hawker center, the visit pattern of participants on shopping mall is highly correlates with the location of the mall itself.

5.3 POI Correlates with Gender and Working Type

The heatmaps according to different gender and working type are presented in Figure 9. The highly active gender corresponding to the working type are highlighted with red bold boxes.

Figure 9: working type w.r.t. gender (a) Non working female, (b) Non Working male, (c) Working female, and (d) Working male. (Top to bottom and Left to right).

First, we observed non working female are more active than non working male elderly. A lot non working female elderly went to the center area for shopping purposes. To name a few common spot for the female participants are Bugis, Marina Square, China Town, Orchard Road, and etc. Based on previous data, we can draw a conclusion that majority of the POI in central area are highly consists of shopping malls etc. Contrast to female participants, non working male participants travel less and mostly spend their time in Bukit Panjang nearby POI. However, we noticed participants are willing travel more than 10 kilometers for religious purposes.

In contrast, working male participants are more active that the female participants in term of traveling around Singapore when they are working. It might be correlates to the work nature and we yet to investigate such occurrence. As for female participants, the heat of maps is shift towards central and bottom part of the Singapore, where the male participants are spread evenly.

Lastly, non working female and working male are most active categories compared to working female and non working male participants. It is hard to determine what is the main factor that segregate the behavior of male and female according to their working type. One things can be studied in our future works maybe can correlates their age and their hobby to determine the actual factor of separation.

6 CONCLUSIONS

In conclusion, this paper introduces an approach to identify ROI and POI where elderly in Singapore prefer to visit and spend their time. Using smartphone based mobile application, it is possible to collect detailed information with quantitative measurement.

In future, our intention is to identify the transportation mode (e.g. walking, taking bus, taking train) of the users, and profile each user by creating a user mobility profile. The multi-sensor data collected from smartphones make it possible to implement sensor fusion techniques to determine high level information about user behavior.

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