My Places Diary – Automatic Place and Transportation-Mode Detection

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ABSTRACT
My Places Diary is a research prototype, available on Google Play, that tracks places and movements of users throughout the day. It includes two innovative features: Firstly users' home and workplaces are detected automatically, based on heuristics derived from earlier work on automatic semantic place detection. Additional place labels are provided via open geo data sources. The position is determined by using a low power positioning method while preserving sufficient accuracy for place detection. Secondly modes of transportation between places (walking, driving, biking) are derived based on Google's activity recognition module. Combining these two features makes My Places Diary an automatically created diary of places and transitions between them. All computations are executed directly on the mobile phone.

Categories and Subject Descriptors
I.5.4. [**Pattern Recognition**]: Applications.

General Terms
Algorithms, Design.

Keywords
Location based services, semantic place detection, activity recognition, Android, transportation mode detection.

1. INTRODUCTION
My Places Diary is an Android research prototype that tracks places and movements of users throughout the day. Users' home and workplaces are detected automatically, based on heuristics derived from earlier work on automatic semantic place detection. Where possible, additional labels are provided based on open geo data sources. The position is determined by using a low power positioning method while preserving sufficient accuracy for place detection. Furthermore, transitions between places are automatically labelled by mode of transportation (walking, driving, biking) using Google's activity recognition module as a basis for detection. The resulting activity recognition estimate is checked for plausibility through evaluating the location history. The user interface displays places and modes of transportation between places on an easy to use map and list overview, which allows for reflection on the user's daily routine. My Places Diary thus creates an automatic diary of visited places as well as transitions between them. The application, including a video and screenshots can be found here: http://tinyurl.com/myplacesdiary.

My Places Diary combines semantic place detection and transport mode detection, which are heavily researched in the mobile sensing community. Prototypes that demonstrate such functionality however are rare. While many applications support labelling places manually, there are no publicly available prototypes that demonstrate assigning labels automatically. CenceMe [5] uses semi-automatic labelling of places based on community data and geo databases. Modes of transportation (walking, sitting, standing, running) are detected but not shown as transitions between places. HealthyLife [1] is able to automatically detect basic transport modes like driving, walking and stationary as well as more complex activities like working hard by combining these basic modes with information from geo databases. Places are labelled manually (home, work) or by querying geo databases. The application Moves[1] uses foursquare, a community generated geo database, to support labelling of places. However place labels are not assigned automatically. Transitions between places are, similar to My Places Diary, shown on a list and map view. In contrast to My Places Diary, the application Moves drains the mobile devices' battery considerably, due to its heavy use of GPS positioning. Therefore it is not suited to be used as a diary running in the background.

2. DETECTING PLACES
There are three main challenges related to place detection: Positioning, clustering positions to places, and labelling places (semantic place detection).

2.1 Positioning
Position refers to identifying a single geographic location of the user. A main challenge with positioning relates to energy consumption. In My Places Diary, the position is obtained by

[1] http://www.moves-app.com/

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using the Android Fused Location Provider (FLP) included in the Google Play Services API. The FLP provides a means of power efficient positioning combining satellite, Wi-Fi and cell positioning as well as several device sensors to adjust the frequency of position updates depending on the movement of the user. For the prototype the balanced power method with an update interval of 1 minute was used.

2.2 Time-based Position Clustering

The positioning service delivers a time series of single positions. Even if a person stays, in human understanding, in one place such as one's own apartment or within a shop, a series of slightly different positions are returned. In order to detect places, a time-based clustering of the recorded positions has to be performed. The algorithm is based on Kang et al. [2]: Positions are clustered based on distance and time. A cluster is considered a place if the total duration is at least 25 minutes. The clustering works as follows: A position is added to a cluster if the distance to the previously collected positions is within a defined limit. This limit has been determined according to the average precision of the positioning method, resulting in a bounding box with a side length of 30 meters. The center of the bounding box is created by averaging the previously collected positions. If a position is not within the bounding box, it is added to a list of potential candidates for a new cluster. The list is deleted if there was only one outlier. If the list keeps growing, a new cluster is created and every new position is evaluated against the clustering condition described above.

Table1: Clustering algorithm

```
parameters
position = current position
cluster = clustered positions
d = maximum distance
t = dwell time
potentialPositions = list of potential
candidates for a new cluster
place = cluster considered a place

calculateCluster(position) {
  if(distance(cluster, position) < d) {
    cluster.add(position)
    potentialPositions.clear();
  }
  else {
    if(potentialPositions.length > 1) {
      if(duration(cluster) > t) {
        place.add(cluster)
       }
       cluster.clear();
       cluster.add(potentialPositions.get(end))
       potentialPositions.clear();

       if(distance(cluster, position) < d) {
         cluster.add(position);
         potentialPositions.clear();
       } else {
         potentialPositions.add(position)
     } else {
       potentialPositions.add(position)
    }
}
```

2.3 Semantic Place Detection

After clustering, a time series of positions and places is available. Places have semantics: A user is in a shop, is at home, in a restaurant etc. In order to label places, two strategies are pursued: Labelling based on (i) open geo databases and (ii) visit patterns.

2.3.1 Labelling based on Open Geo Data Sources

In order to make sense in terms of the visited address or the label of a place of specific interest, a number of geo databases are queried (OpenStreetMap, Google Places and Geonames). Since the granularity and consistency of OpenStreetMap (OSM) far exceeds other publicly available geo data sources, the Overpass OSM query API forms the basis for all reverse geocoding operations. The most probable label for a place is determined by executing a nearest neighbour query with the center coordinate of the place as origin. If OSM fails to reply with an adequate address or label response, the response is merged with other geo data providers such as Google Places or Geonames. If the user has spent time at a very remote location, where neither a place label nor an address is available, the name of the region is returned.

2.3.2 Labelling Users' Home and Workplace based on Visit Patterns

Based on the dataset, collected by the Lausanne Data Collection Campaign [3], Lex et al. [4] showed that the place where users are most between 8am and 4pm is the workplace (school for students), and the place where users are most between midnight and 4am is home. The places identified by the clustering algorithm, which intersect these time intervals, are marked as possible candidates for home or workplace. The place with the longest staying time in the heuristically identified timespans is classified as home or workplace. In order to make the classification more robust, special cases such as weekends and fluctuations in the workplace position are considered as well.

3. TRANSPORT MODE DETECTION

The transport mode detection is based on Google's activity recognition module included in the Play Services API. The detection mainly relies on the device's accelerometer data and thus enables power efficient detection. The modes that can be detected are walking, biking, driving, tilting and unknown. In My Places Diary, the transport mode detection is checked for plausibility by evaluating against the recorded history of positions. This is done by calculating the average travel velocity of the user for a transition and comparing it to typical average speeds of the transport mode classes.

4. DISCUSSION AND CONCLUSION

My Places Diary is a research prototype that combines features from two highly researched fields in mobile sensing in a stable application usable by non-tech-savvy end users: semantic place detection and transport mode detection. We aimed for energy-efficient, often heuristic-based algorithmic implementations. My Places Diary is intended to demo to non-researchers what semantic place detection and transport mode detection can achieve. Evaluations of algorithmic correctness are part of our future work. The following paragraphs present an overview of challenges and future improvements of the technologies used for the research prototype My Places Diary.

4.1 Positioning

The localization of the mobile phone is based on Wi-Fi positioning when choosing the balanced mode of the FLP and delivers sufficient accuracy at around 30 meters, when used in urban areas. However, when entering rural surroundings, sparse coverage of Wi-Fi networks causes positioning inaccuracies. Another issue is that the localization method employed in urban areas expects the received signal strength to fade to a certain level for a specific position. In some cases more Wi-Fi networks than typical for a certain position have been detected. This is particularly the case when scanning for radio fields at local peaks or at the upper levels of multi-story buildings. To overcome these problems, the GPS module of the mobile phone could be activated on demand, as an additional positioning method. Since the Wi-Fi fingerprinting method requires an internet connection to resolve the position, this would also guarantee continuous positioning in case connectivity is lost. Poor Wi-Fi positioning would diminish the quality considerably, with two error cases being the most prevalent: (i) position is fluctuating: in this case, the place recognition prerequisite would never be met (ii) position is stable, but inaccurate: false places visited would be recognized. If no Wi-Fi networks are available, the positioning method currently falls back to cell positioning, which has a poor accuracy around 1-2 kilometres. Although Wi-Fi positioning for localization of the mobile phone is used, My Places Diary does not provide precise indoor positioning. To enable precise indoor positioning the application could be extended to support user generated radio maps of buildings based on Wi-Fi signals or Bluetooth beacons. This could be accomplished by simultaneous localization and mapping (SLAM).

4.2 Semantic Place Detection

The chosen dwell time of 25 minutes for clustering positions is based on Kang et al. [2]. By using this interval, cluttering the diary with insignificant places has largely been avoided. However by not considering places the user visited only for a short period of time, errors such as detecting multiple types of transitions between two places can occur. The place labelling based on open geo databases determines the label by performing a nearest neighbour query with the center coordinate of the place. The point of interest (POI) with the smallest distance to the center coordinate is assumed to be the most probable one. Since it is possible that there are multiple POIs for one place, the position is inaccurate, or POIs are simply not available in the database, this holds not always true, though. For the future the user should be able to additionally annotate the place label or choose from a list of suggestions. The suggestions should be improved over time with the help of the user feedback. The heuristic based labelling of home and workplace is very limited, not evaluated, and has only two classes. Also the calculation of home and workplace is done on a daily basis at the moment. In the future a long term analysis of those places will be implemented to avoid e.g. holiday locations to be classified as home or workplace. Also the long term analysis could cover places that are visited only for a short time but frequently and thus are also of interest to the user. Additional place labels will be subject to future research.

4.3 Transport Mode Detection

The transport mode detection is based on Google's activity recognition module. By using the activity recognition module the need for manually implementing the detection algorithms, recording and training the data set was avoided. Also a well integrated, moderately accurate and energy efficient detection directly on the mobile phone was possible. However the details of the implementation of the module are not accessible which makes improvements or extensions to support further activities or modes of transportation impossible. Problems that occurred were e.g. mixing up driving with biking when in stop-and-go traffic or not detecting any transport mode while using the phone. To overcome these problems, a transportation mode detection module which stabilizes the accelerometer based detection will be implemented. This will be achieved by additionally using GPS or Wi-Fi positioning, as well as including a pose model for different phone positions.

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