Mobility Collector

Battery Conscious Mobile Tracking

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Outline

Location tracking

Current technological status

**Mobility Collector** - a mobile tracking platform

Spatial and temporal granularity in location-dependant data

Robust data linking spatial with physical movement

Usability of **Mobility Collector**
Location Tracking

There is a need for location awareness:

a) Multi-user systems
   - Studying behavior and movement
   - Extrapolating information (prediction)

b) Single-user systems
   - Ubiquitous (pervasive) computing
   - Studying and understanding the user’s context
   - Aiding the user in decision making
Tech status for location tracking

The industry’s focus is on purpose-oriented apps

Research development is not a priority

The location listening service is acontextual

Temporal granularity has precedence over the spatial one

Multiple API’s, different software implementation and ambiguous documentation
Mobility Collector

A highly configurable tracking platform for Android devices (Android 2.0 and higher)

Research oriented and open-source

Equidistant and equitime tracking options

Contextual battery preserving algorithm

Configurable point- and period-based annotations
Why Android?

Open-source

Offers hardware and software diversity

Mobility Collector - minimum API 5

<table>
<thead>
<tr>
<th>Version</th>
<th>Codename</th>
<th>API</th>
<th>Distribution</th>
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<tbody>
<tr>
<td>2.2</td>
<td>Froyo</td>
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<td>2.2%</td>
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<td>2.3.3-2.3.7</td>
<td>Gingerbread</td>
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<td>Honeycomb</td>
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<tr>
<td>4.2.x</td>
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<td>17</td>
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<tr>
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<td>1.5%</td>
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Tracking algorithms

Equit ime and Equidistant tracking
Parameters

**Sampling time** - the frequency at which the location listener will try to obtain a fix

**Sampling distance** - the clustering constraint which prevents locations to be broadcasted if they are within a certain distance of the last fix
Equitime tracking

Time: $T_c + 30$ seconds

$L_p(1)$ gets broadcasted

$L_p$ - potential location

$L_c$ - current location
Equitime tracking

Time: $T_c + 30$ seconds

$L_p(1)$ gets broadcasted

$L_p(1)$ fails the clustering filter

$L_p$ - potential location

$L_c$ - current location
Equitime tracking

Time: $T_c + 1$ min

$L_p(2)$ gets broadcasted

$L_p$ - potential location
$L_c$ - current location
Equitime tracking

Time: $T_c + 1$ min

$L_p(2)$ gets broadcasted

$L_p(2)$ fails the clustering filter

$L_p -$ potential location

$L_c -$ current location
Equitime tracking

Time: $T_c + 1.5 \text{ min}$

$L_p(3)$ gets broadcasted

$L_p$ - potential location

$L_c$ - current location
Time: $T_c + 1.5$ min

$L_p(3)$ gets broadcasted

$L_p(3)$ passes the clustering filter
Time: $T_c + 1.5$ min

$L_p(3)$ gets broadcasted

$L_p(3)$ passes the clustering filter

$L_p(3)$ gets sent to the programming interface

$L_p$ - potential location

$L_c$ - current location

Equitime tracking
Time: $T_c + 1.5 \text{ min}$

$L_p(3)$ gets broadcasted
$L_p(3)$ passes the clustering filter
$L_p(3)$ becomes the reference for future fixes

$L_p$ - potential location
$L_c$ - current location
$L_f$ - former instance of $L_c$
Equidistant tracking

- $L_c$ - current location
- $F_p$ - predicted frequency
- $F_c$ - current frequency
- $req$ - the requirements imposed by the $F_c$ on the list size

Flowchart:

1. **Feed** $L_c$ to **Location_List**
2. **size(list)**
   - **Yes**
     - **Renew(list, L_c)**
       - $F_p = \min_{freq}(list)$
   - **No**
     - **Add(list, L_c)**
3. **|F_p - F_c|**
   - **relevant**
     - **Yes**
       - update **Location_listener(F_p)**
       - $F_c = F_p$
       - update **size(list)**
       - **req**
Equidistant tracking

L_c - current location
F_p - predicted frequency
F_c - current frequency
req - the requirements imposed by the F_c on the list size

Flowchart:
- L_c → Feed → Location_List
- size(list) → req
  - Yes → Renew(list, L_c)
    - F_p == min_freq(list)
  - No → Add(list, L_c)
- |F_p - F_c| → relevant
  - Yes → update Location_Listener(F_p)
    - F_c == F_p
    - update size(list) req
L_c - current location
F_p - predicted frequency
F_c - current frequency
req - the requirements imposed by the F_c on the list size

Equidistant tracking

Feed

Location_List

size(list) req

Renew(list,L_c)
F_p == min_freq(list)

Add(list,L_c)

|F_p - F_c| relevant

- update Location_Listener(F_p)
- F_c == F_p
- update size(list) req
Equidistant tracking

- \(L_c\) - current location
- \(F_p\) - predicted frequency
- \(F_c\) - current frequency
- req - the requirements imposed by the \(F_c\) on the list size

**Flowchart Description**

1. Feed \(L_c\) to Location List
2. Check size(list) req
   - Yes: Renew(list, \(L_c\)) \(F_p = \min\_freq\) (list)
   - No: Add(list, \(L_c\))
3. Check \(|F_p - F_c|\) relevant
   - Yes: Update Location Listener(F_p) \(F_c = F_p\) Update size(list) req
Equidistant (Blue)
Equitime (Red)

Sampling time = 50 s
Sampling distance = 50 m
Equitime vs. Equidistant Tracking

Equidistant (Blue)
Equitime (Red)

Sampling time = 50 s
Sampling distance = 50 m
Equitime vs. Equidistant Tracking

Graphs showing the time and distance between locations for Equitime and Equidistant tracking.
Equitime vs. Equidistant Tracking

Equidistant specific adjustment
Equitime vs. Equidistant Tracking

- **Time between locations**
  - Graph showing time value (s) over trip time (min) for Equidistance and Equitime.

- **Distance between locations**
  - Graph showing distance value (m) over trip time (min) for Equidistance and Equitime.
### Equitime vs. Equidistant Tracking

**Sampling time = 50 s**

**Sampling distance = 50 m**

<table>
<thead>
<tr>
<th>Stats</th>
<th>Equitime</th>
<th></th>
<th>Equidistant</th>
<th></th>
<th>Equidistant – after initialization</th>
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<tr>
<td></td>
<td>Distance (m)</td>
<td>Time (s)</td>
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<td>Distance (m)</td>
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<tr>
<td>Avg</td>
<td>287.9</td>
<td>98.1</td>
<td>64.2</td>
<td>15.8</td>
<td>56.1</td>
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<td>Std. Dev.</td>
<td>141.9</td>
<td>50.7</td>
<td>30.8</td>
<td>19.2</td>
<td>6.0</td>
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<tr>
<td>Min</td>
<td>61.3</td>
<td>67.0</td>
<td>50.1</td>
<td>3.0</td>
<td>50.1</td>
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<tr>
<td>Max</td>
<td>562.4</td>
<td>250.0</td>
<td>204.9</td>
<td>102.0</td>
<td>82.0</td>
</tr>
<tr>
<td># of Records</td>
<td>15</td>
<td></td>
<td>82</td>
<td></td>
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Equitime vs. Equidistant Tracking

1. Low number of records
2. Time for the “actual” fix

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Sampling time = 50 s
Sampling distance = 50 m
# Equit ime vs. Equidistant Tracking

Sampling time = 50 s  
Sampling distance = 50 m

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Case study

OSM-derived semantics

Speed fluctuations

Trip time (min)

0 10 20 30 40 50 60

10 20 30 40 50 60

Equidistant Tracking
Equitime Tracking
Case study

Analysis (based on proximity) result:
L1 - traffic light
L2, L4 - bus stop
L3 - no features of interest in its vicinity
## Equitime vs. Equidistant Tracking

<table>
<thead>
<tr>
<th>Equitime tracking</th>
<th>Equidistant tracking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good for general purpose apps</td>
<td>Good for inferring context</td>
</tr>
<tr>
<td>Spatial granularity is of little or no importance</td>
<td>Spatial granularity takes precedence over the temporal one</td>
</tr>
<tr>
<td>Linear battery drainage</td>
<td>Battery drainage depends on the speed of the phone bearer</td>
</tr>
</tbody>
</table>
Data (in)sufficiency

Speed fluctuation

- Speed (km/h)
- Time (min)
Data (in)sufficiency

Location data $\Leftrightarrow$ spatial displacement
Location data $\neq$ movement
Physical context makes the data robust

Walking

No relevant movement
Embedded accelerometer

Basic statistics measurements (average, std. dev., min, max) for all axis and for total acceleration

Movement detection

Number of peaks

Pedometer
Embedded accelerometer

Basic statistics measurements (average, std. dev., min, max) for **all axis** and for **total acceleration**

Movement detection

Number of peaks

Pedometer

![Diagram](image-url)
Usability

Battery drainage restricts the number of candidates in most research experiments.

Users should still be able to use their phones while collecting data without having to worry about a battery overkill.
The alarm has two instances:

- location instance (spatial context)
- accelerometer instance (physical context)
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- location instance (spatial context)
- accelerometer instance (physical context)
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- location instance (spatial context)
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Battery Saving Results
Annotations are particularly useful:

- For obtaining **training samples** for different types of classifications
- As a measure of **(re)assurance** for the correctness of particular types of algorithms
- Adding a **spatial component** to qualitative data types
Point- and period-based annotations

Time of the event
Point- and period-based annotations

Time of the event
Using Mobility Collector

Service running in Alfa mode on a VM at: http://130.237.68.66:8080/Mobility_Collector_Form/HomePage.jsp

Tutorials and future references will be posted on GitHub

Android Application Source Code: https://github.com/adrianprelipcean/Mobility_Collector_Android

Apache Tomcat Servlet Source Code: https://github.com/adrianprelipcean/kth_mobility_collector
Summary

- Location tracking, its importance and current status
- Mobility Collector - a mobile tracking platform
- Equitime and equidistant tracking
- Data sufficiency and robustness
- Usability of Mobility Collector
Thank you!

Q&A?

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adrianprelipceanc@gmail.com