



# Building a Personal Symbolic Space Model from GSM CellID Positioning Data

Filipe Meneses, Adriano Moreira

[ubicomp@uminho](mailto:ubicomp@uminho)

Mobile and Ubiquitous System Group

<http://ubicomp.algoritmi.uminho.pt>

Mobilware 2009 – Berlin, April 28<sup>th</sup>



## Outline

- Motivation
- Positioning model
- Movement tracking
- Personal symbolic space model
- Experimentation



# Motivation

- User's position can be acquired using a number of different technologies:
  - GPS
  - Active Bat
  - Ubisense
  - WiFi networks
- Geometric positioning vs locations information
- The context of a person is more than a pair of coordinates or the name of a place. It is the type of place, with whom the person is, how often a person visits a place, etc.



# Positioning Model (I)

- GSM
  - Mobile phone are well integrated in everyday life;
  - Turned on most of the time;
  - GSM networks are ubiquitous;
  - The mobile phone as a proxy to capture the context of a mobile user.



## Positioning Model (II)

- GSM network
  - Telecommunications cellular network;
  - Made of cells with different size and shape;
  - The handset is linked to a cell – the active cell;
  - Each cell supports only a limited number of channels;
  - CellID positioning provides the handset location in a symbolic referential
    - Could be converted into the geographic position of the handset;
    - In fact, people on their living, deal with location in a symbolic referential (like “home”, “office”, etc.);
- The positioning model adopted in this work is based on the detection of movement within the space model of GSM cells.



## Movement Tracking (I)

- Movement Tracking
  - Based on changes in the active cell;
  - When the terminal is stopped in a certain place, the sequence of active cells is limited to the set of cells that cover the terminal’s position;
  - Infer the user motion by analysing the changes in the serving cell and amount of time spent on each cell;

$$MobilityDistance(r_1, r_2) = \begin{cases} 0 & \text{if } r_1 = r_2 \\ \frac{1}{time(r_1)} + \frac{1}{time(r_2)} & \text{if } r_1 \neq r_2 \end{cases}$$

- When the user is moving fast the time spent in a cell is small;

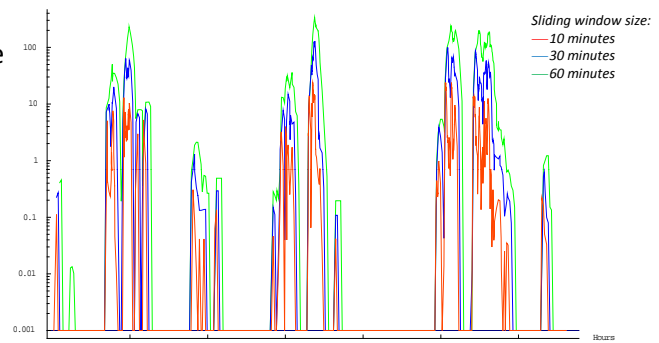
$$MobilityIndex(r_{1..n}) = \sum_{i=1}^n \sum_{j=1}^i MobilityDistance(r_i, r_j)$$

- The user mobility level can be estimated by calculating the Mobility Index over a pre-defined period of time;
- For a set of consecutive records it is possible to create a sliding window and calculate the Mobility Index as the time goes by;

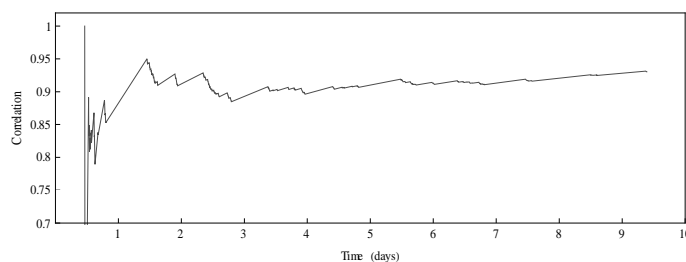


## Movement Tracking (II)

- Mobility index varies according to the size of the sliding window;
- To detect the user movements we defined a threshold based on sliding window size.



- Movement tracking validation:



Correlation between the mobility periods calculated from GPS data and from the Mobility Index

Sliding window: 10 minutes  
Threshold: 6



## Personal Symbolic Space Model (I)

- Mobility Index allows to detect when the user starts and stops moving;
  - Characterize the previously visited place: creating a **fingerprint** with the list of cells observed during the time the user was not moving

$$FP = \{\{cellID_1, timePercentage_1\}, \{cellID_2, timePercentage_2\}, \dots, \{cellID_n, timePercentage_n\}\}, totalTime, timeStamp$$

- (However) Different visits to the same place create different fingerprints;
- Clustering similar fingerprints;
  - To create a cluster it is necessary to measure the similarity between fingerprints

$$FPDistance(FP^A, FP^B) = (0.5 \times HDistance(FP^A, FP^B)) + (0.5 \times SimilarityDistance(FP^A, FP^B))$$



## Personal Symbolic Space Model (II)

- New clustering algorithm
  - Data do be clustered is symbolic (the fingerprints);
  - Clusters are to be discovered in real time;
  - The total number of clusters is not know in advance;
  - The number of clusters is the number of places visited by the user.



## Personal Symbolic Space Model (III)

- The clustering process
  - 1<sup>st</sup> fingerprint -> 1<sup>st</sup> cluster
  - Calculate the similarity between the fingerprint and each cluster
    - Join the cluster if similarity is smaller than a pre-defined threshold
  - Create a new cluster
  - Replace an existent cluster

$$FCIR(cl, fp) = \frac{KldgIdx(\pi(fp))}{FgIdx(Age(cl, fp)) \times KldgIdx(\pi(cl))}$$

- Familiarity index
  - Important places are usually visited more often and the user spends more time there (like home or office)

$$FmIdx(cl) = KldgIdx(cl) \times FgIdx(cl)$$



## Experimentation (I)

- Data collection
  - Application on a Symbian phone;
  - Checks the cellID every eight seconds and records it on a log file;
  - Three different users collected data during several consecutive weeks;
  - Simultaneously manually recorded their movements on a diary;
- Clustering process
  - Similarity threshold: 65%



## Experimentation (II)

- Trial users' results

	User A	User B	User C
Places visited by the user	4	27	29
Places detected	3 (16 clusters)	19 (21 clusters)	22 (30 clusters)
Places not detected	1	8	7
False positives	1 cluster	4 clusters	6 clusters

- A detailed analysis of the achieved results can explain many of the errors



## Experimentation (III)

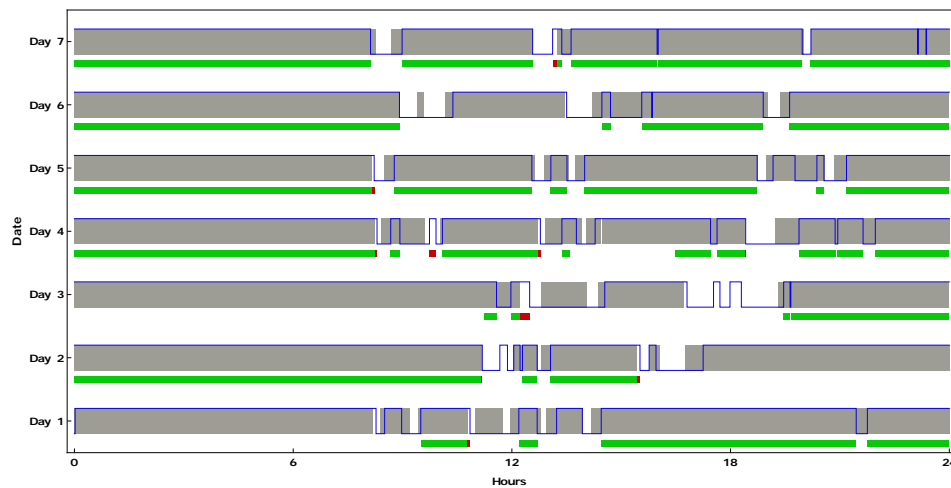
Results achieved considering the visits made to each place

User A	2 places	53 visits	53 detected visits	100%
	1 place	6 visits	3 detected visits	50%
	1 place	3 visits	0 detected visits	0%
User B	18 places	58 visits	58 detected visits	100%
	3 places	71 visits	62 detected visits	87%
	6 places	9 visits	0 detected visits	0%
User C	12 places	18 visits	18 detected visits	100%
	10 places	133 visits	116 detected visits	87%
	7 places	11 visits	0 detected visits	0%



## Experimentation (IV)

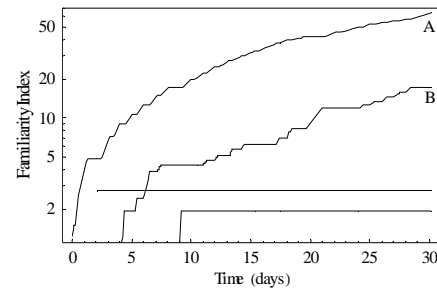
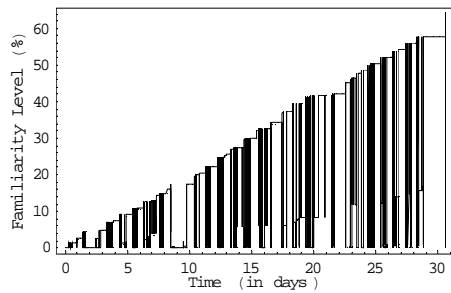
User agenda overlapped with the tracking and recognizer results





# Experimentation (V)

- Using the Personal Symbolic Space Model
  - Identify the places visited by the user
  - A Familiarity Index can be valuable for different applications



Ubicomp@uminho – <http://ubicomp.algorithmi.uminho.pt>



Questions?

**Thank you!**

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