# Sensor signal data set for exploring context recognition of mobile devices

Jani Mäntyjärvi[*], Johan Himberg[+], Petri Kangas[^], Urpo Tuomela[^], Pertti Huuskonen[¤]

[*]VTT Electronics, P.O. Box 1100, FI-90571 Oulu, Finland
Jani.Mantyjarvi@vtt.fi

[+]Helsinki University of Technology, Lab. of Computer and Information Science
P.O. Box 5400, FI-02015 HUT, Finland
johan.himberg@hut.fi

[^]Nokia Corporation, P.O. Box 300, FI-90401, Oulu, Finland,
{petri.kangas,urpo.tuomela}@nokia.com

[¤]Nokia Research Center, Visiokatu 1, FI-33720 Tampere, Finland,
pertti.huuskonen@nokia.com

**Abstract.** This position paper describes a motivation for a sensor signal data set for exploring context recognition of mobile devices. Test scenarios, collection and pre-processing of data are briefly described. The data set has already been used in various studies on context sharing, rule based context inference for context-aware user interfaces, and pattern recognition. A list of related literature is given.

## 1 Introduction

Mobile devices with their users are constantly moving in various situations. Thus, it is very attractive to develop context-based novel functionality, services and applications into mobile devices. To detect various usage situations methods for recognising contexts must be developed. One approach is to use several low cost sensors integrated into a mobile device and try to find patterns from signals that correspond to certain real life usage patterns. We wanted to focus on monitoring user activity and environment, thus we chose sensor-centric approach to investigate context recognition. There is a very little knowledge extracting contexts from sensors integrated into mobile devices. Thus, our approach is data centric; to examine signals carefully using data-analysis methods and develop context recognition and context utilisation methods from 'bottom-up'.

## 2 Data Collection

### 2.1 Data logging device

We have used the sensor box built for examining context-awareness of mobile devices. Sensors are placed into a small sensor box, which can be attached into a mobile device, Figure 1. Two two-axes accelerometers are placed inside a sensor box and connected to measure accelerations of the device in three orthogonal directions. All other sensors measuring environmental conditions and skin conductivity are placed into the cover of the box. In the experiments, signals from sensors are A/D-converted and sampled at 256 Hz, 12-bit using DaqCard 1200 measurement board that is connected to a laptop computer. The audio signal is A/D-converted and sampled at 22.05 kHz, 16-bit, using a standard audio card of a laptop computer. Time labels are attached to measurement values. Raw data and processed context atoms are stored on files.

Figure 1. Sensor box for examining context-awareness of mobile devices.

Table 1. Context information sources and their descriptions.

| Information source (sensor) | Description |
| --- | --- |
| Accelerometer x-, y-, z- axis (type ADXL202JQC) | Measures accelerations of the device in orthogonal directions |
| Illumination (type IPL10530D) | Measures the level of the illumination in immediate environment of a device |
| Thermometer (type TMP36F) | Measure the level of the temperature in immediate environment of a device. |
| Humidity sensor (HIH-3605-B) | Measures the level of the air humidity in immediate environment of a device. |
| Skin conductivity sensor (self-made) | Detects a contact between a device and the hand of a user. |
| Microphone (customized) | Measures audio from immediate environment of a device. |

## User scenarios

To examine context recognition of a mobile device and its user data from normal user routines and device's usage environment must be collected. We have designed five user scenarios described in Table 2. Two users went through each of the 5 scenarios described in Table 2 about 25 times each. Scenarios lasted about 2 to 5 minutes. When the terminal was not on the table it was hanging in front, from the user's neck. The data was annotated with video recordings. One sample recording was collected form each of the scenario. Later on the video recordings were sliced into picture sequences and time was synchronised with sensor data enabling qualitative examination of data analysis.

Table 2. Descriptions of user scenarios

| | **Activities** | | **Location** |
|---|---|---|---|
| Scenario 1 44 Recordings | Device on table | Inside | Office room |
| | Device in hand | Inside | Office room |
| | Walking | Inside | Corridor |
| | Walking | Inside | Down the stairs, lobby |
| | Walking | Outside | Street |
| | Walking | Inside | Lobby |
| | Walking | Inside | Up the stairs, corridor |
| | Device in hand | Inside | Office room |
| | Device on table | Inside | Office room |
| Scenario 2 48 Recordings | Device on table | Inside | Office room |
| | Device in hand | Inside | Office room |
| | Walking | Inside | Corridor, downstairs |
| | Halt | Inside | Mail lockers |
| | Walking | Outside | Backyard |
| | Halt | Inside | Mail lockers |
| | Walking | Inside | Up the stairs, corridor |
| | Device in hand | Inside | Office room |
| | Device on table | Inside | Office room |
| Scenario 3 49 Recordings | Device on table | Inside | Office room |
| | Device in hand | Inside | Office room |
| | Walking | Inside | Corridor |
| | Halt | Inside | Lift upstairs |
| | Walking | Inside | Corridor |
| | Halt | Outside | Balcony |
| | Walking | Inside | Corridor |
| | Halt | Inside | Lift downstairs |
| | Walking | Inside | Corridor |
| | Device in hand | Inside | Office room |
| | Device on table | Inside | Office room |

| | | | |
|---|---|---|---|
| Scenario 4 50 Recordings | Device on table | Inside | Office room |
| | Device in hand | Inside | Office room |
| | Walking | Inside | Corridor |
| | Sitting+talking | Inside | Meeting room |
| | Walking+talking | Inside | Corridor |
| | Sitting+talking | Inside | Coffee room |
| | Walking | Inside | Corridor |
| | Device in hand | Inside | Office room |
| | Device on table | Inside | Office room |

| | | | |
|---|---|---|---|
| Scenario 5 50 Recordings | Device on table | Inside | Office room |
| | Device in hand | Inside | Office room |
| | Walking | Inside | Corridor |
| | Halt | Inside | Lift upstairs |
| | Walking | Inside | Corridor |
| | Halt | Inside | Lift downstairs |
| | Walking | Inside | Corridor |
| | Device in hand | Inside | Office room |
| | Device on table | Inside | Office room |

Sensor signals are further processed to generate context atoms that are used in various experiments to examine context recognition [1, 2, 3, 4, 5, 6, 11], context sharing [7, 8, 11], and context-aware applications [9, 10, 11]. In [1,2] data set is used in context time-series segmentation and clustering. In [3,4] data set is used in examining context data projection pursuit and compression. In [4,5,6] data set is used in finding instantaneous and temporal patterns in discrete context atom data. To make the data discrete, fuzzy context atoms are threshold to either zero or one if necessary. A description of the signal processing, feature extraction, and context recognition related and a survey to the field of context recognition is provided in [11].

## 3. Availability of the data

The data set is provided in an ASCII flat file. One or two tests in each scenario have related low-resolution video captures with a JPEG-image every two seconds. (http://www.cis.hut.fi/jhimberg/contextdata)

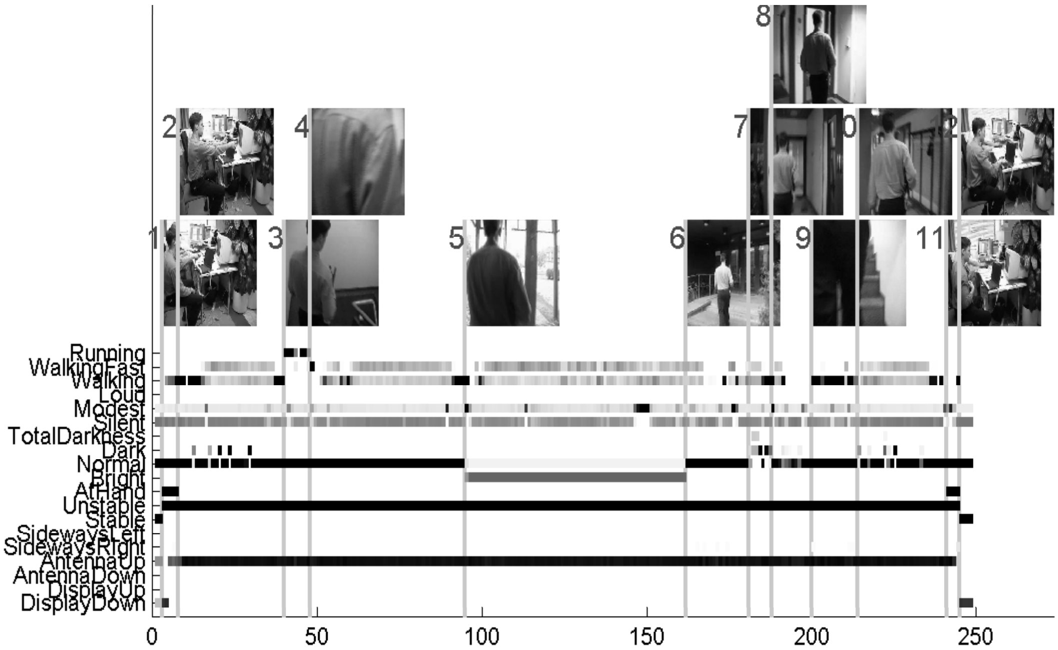


Figure 2: Context atom data from a single walk-through of Scenario 1 and some related video frames. A selection of context atoms is encoded using grey levels (0=white, 1=black). The vertical grey lines indicate the time when the event in the thumbnail image occurred. X-axis indicates elapsed time in seconds.

## 4. Conclusions

Context-awareness in mobile devices can be implemented as designed, rule-based guidance. Another approach is to use machine learning to infer the context. Machine learning requires enough quality data. We have collected such data set from known user scenarios in ordinary office scenarios in order to study machine learning and traditional plug-in rule based approach into context-awareness. The data set has already been valuable in studies on context sharing e.g., using ad hoc networks; rule based context inference for context-aware user interfaces; and pattern recognition using clustering, time series segmentation and projection pursuit.

## Acknowledgements

Mr. Mika Herrala and Mr. Ville-Pekka Karhu are acknowledged for performing the data collection.

## References


1. J. Mäntyjärvi, J. Himberg, P. Korpipää, and H. Mannila. Extracting the Context of a Mobile Device User. In Proceedings of the 8th IFAC IFAC/IFIP/IFORS/IEA Symposium on Analysis, Design, and Evaluation of Human-Machine Systems (IFAC HMS 2001), pp. 450-500, Kassel, Germany, 2001.
2. J. Himberg, K. Korpiaho, H. Mannila, J. Tikanmäki, and H.T.T. Toivonen. Time series segmentation for context recognition in mobile devices. In Proceedings of the 2001 IEEE International Conference on Data Mining (ICDM 2001), pp. 203-210, San José, California, USA, 2001.
3. J. Himberg, J. Mäntyjärvi, and P. Korpipää. Using PCA and ICA for exploratory data analysis in situation awareness. In Proceedings of the 2001 IEEE International Conference on Multisensor Fusion and Integration for Intelligent Systems (MFI 2001), pp. 127-131, Baden-Baden, Germany, 2001.
4. J.A. Flanagan, J. Himberg, and J. Mäntyjärvi. A Hierarchical Approach to Learning Context and Facilitating User Interaction in Mobile Devices, in Artificial Intelligence in Mobile System 2003 (AIMS 2003) (in conjunction with Ubicomp 2003), October 12, Seattle, USA.
5. J. A. Flanagan, J. Mäntyjärvi, and J. Himberg. Unsupervised clustering of symbol strings and context recognition. In Proceedings of the 2002 IEEE International Conference on Data Mining (ICDM 2002), pp. 171-178, Maebashi, Japan, 2002.
6. J. Himberg, J. A. Flanagan, and J. Mäntyjärvi. Towards Context Awareness Using Symbol Clustering Map. In Proc. Workshop for Self-Organizing Maps 2003 (WSOM2003), pp. 249-254, Kitakyushu, Japan, 2003.
7. J. Mäntyjärvi, J. Himberg, and P. Huuskonen, Collaborative context recognition for handheld devices. In the Proceedings of the International IEEE Conference on Pervasive Computing and Communications (PerCom), Dallas, USA. Pp.161–168, 2003.
8. J. Mäntyjärvi, P. Huuskonen, and J. Himberg, Collaborative context determination to support mobile terminal applications. IEEE Wireless Communications Vol. 9(5): 39–45, 2002.
9. J. Mäntyjärvi and T. Seppänen, Adapting applications in handheld devices using fuzzy context information. Interacting with Computers Journal, Vol. 15(4), pp. 521–538, 2003.
10. J. Mäntyjärvi, U. Tuomela I. Känsälä & J. Häkkilä, 2003. Context studio – tool for personalizing context-aware applications in mobile terminals. In the Proceedings of the conference for the Computer-Human Interaction Special Interest Group of the Ergonomics Society of Australia, 2003.
11. J. Mäntyjärvi. Sensor-based context recognition for mobile applications. PhD Thesis, Oulu University, Finland. In series VTT Publications 511. VTT Technical Research Centre of Finland, Espoo, Finland, 2003. http://www.vtt.fi/inf/pdf/publications/2003/P511.pdf