SenSay: A Context-Aware Mobile Phone

Daniel Siewiorek, Asim Smailagic, Junichi Furukawa, Andreas Krause, Neema Moraveji, Kathryn Reiger, Jeremy Shaffer, and Fei Lung Wong
Human Computer Interaction Institute and Institute for Complex Engineered Systems
Carnegie Mellon University, Pittsburgh, PA 15213, USA
{dps, asim}@cs.cmu.edu, {junichif, krausea, nmoravej, kr, jshaffer, flw}@andrew.cmu.edu

Abstract

SenSay is a context-aware mobile phone that adapts to dynamically changing environmental and physiological states. In addition to manipulating ringer volume, vibration, and phone alerts, SenSay can provide remote callers with the ability to communicate the urgency of their calls, make call suggestions to users when they are idle, and provide the caller with feedback on the current status of the SenSay user. A number of sensors including accelerometers, light, and microphones are mounted at various points on the body to provide data about the user's context. A decision module uses a set of rules to analyze the sensor data and manage a state machine composed of uninterruptible, idle, active and normal states. Results from our threshold analyses show a clear delineation can be made among several user states by examining sensor data trends. SenSay augments its contextual knowledge by tapping into applications such as electronic calendars, address books, and task lists.

1. Introduction

SenSay (*sen*sing & *say*ing) is a context-aware mobile phone that modifies its behavior based on its user's state and surroundings. It adapts to dynamically changing environmental and physiological states and also provides the remote caller information on the current context of the phone user. To provide context information SenSay uses light, motion, and microphone sensors. The sensors are placed on various parts of the human body with a central hub, called the sensor box, mounted on the waist (see Figure 1).

SenSay introduces the following four states: Uninterruptible, Idle, Active, and the default state, Normal. A number of phone actions are associated with each state. For example, in the Uninterruptible state, the ringer is turned off.

In a much more limited context the idea of smart appliances and phones was explored in [1], [3], [4] and [5]. In [2] concepts of context-aware computing and wearable devices have been described.

Figure 1. SenSay: sensor box mounted on the hip (left), the mobile phone (center), and voice and ambient microphones mounted on the user (right).

2. SenSay Architecture

A three-tier architecture was adopted: the sensor box, decision module, and phone. The following components are shown in Figure 2. The sensor module, located in the bottom left, collects physical sensor data, which are then sent to the notebook computer (henceforth called the platform) through the serial port. The decision module at the top is then notified of data arrival, and a series of preprocessing steps are done to the incoming data before the data is acted upon. Finally, the decision module instructs the phone to act based on the current user context. The decision module utilizes another serial port to communicate with the phone.

3. SenSay Logic

The decision module inspects the gathered data and determines the state that the phone should enter. To prevent bouncing between states too quickly, up to ten minutes of recent sensor data are stored and examined. Running averages are computed to give reasonable weight to previous data and phone state. Furthermore, four states are identified by the system, representing descending levels of uninterruptibility.

The system enters *uninterruptible state* when the user is involved in a conversation or has scheduled an important event in the electronic calendar. Once the phone is in this state, all incoming calls are automatically responded to with SMS messages. The ringer is disabled; vibrate is enabled only when the light level is low. The caller has an

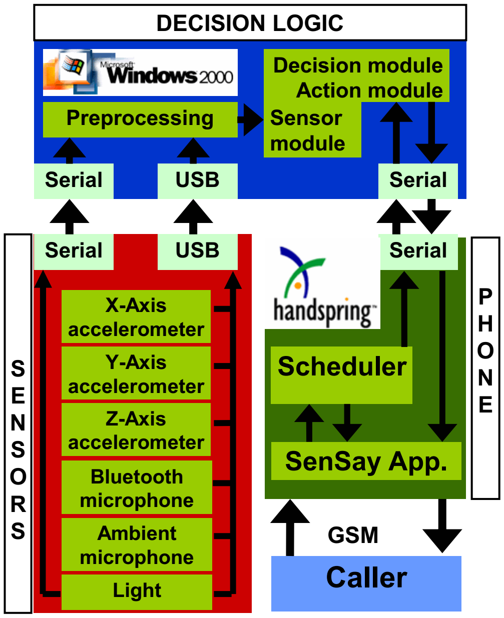

Figure 2. System architecture

option to override this in case of emergency by calling again within three minutes. High physical activity or high ambient noise level puts the system into *active state*. The ringer is set to high and vibrate is enabled. The system goes into *idle state* when there is very little movement and low ambient level. The system reminds the user of missed calls and provides suggestions to the user. In *normal state*, the ringer and vibrate modes are set to the phone's default values.

4. Experiment

A series of threshold analyses tests were run while recording sensor values and noting trends over time. Microphones and accelerometer values were recorded from eleven subjects. In addition to the raw sensor values, average sensor values were also observed over various periods of time.

As an example of threshold experiments, consider user activity. The sensor board was taped to the user's abdomen. The physical activity test was run using the 3-axis accelerometer. The maximum of the three absolute component values was used as the movement data. The data is split into three ranges. *Low Activity* includes sitting, sleeping, etc. Short, intense movements are averaged out. *Medium Activity* represents walking or other comparable activity. Medium movement indicates that the user is not idle. *High Activity* includes movements such as running.

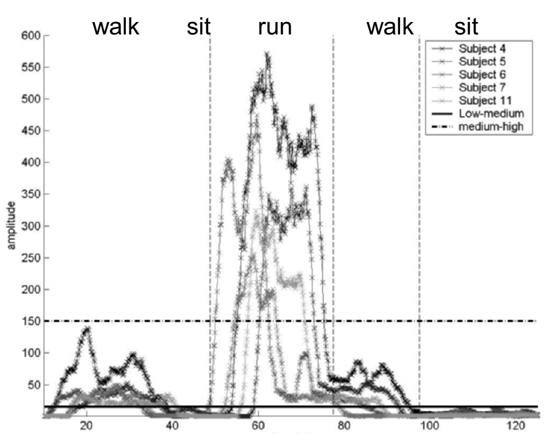

Figure 3. Motion state thresholds

To find generic threshold values, eleven subjects were asked to perform a test: After walking for 40 sec., they were asked to sit down for 10 sec. Then they were required to run for 30 sec. and afterwards walk again. After walking for 20 more sec., they sat down again for an additional 25 sec. Figure 3 shows the resulting values. From this experiment, thresholds for differentiating between low, medium and high activity were found and annotated on the diagram. Other tests were conducted for the microphones and light sensors.

5. Conclusions

SenSay combines sensory data, user information and history information to create a context-aware phone that improves the overall usability of the cell phone. Our threshold analyses on sensor data indicate that it is possible for a mobile phone to derive particular characteristics of user state.

Acknowledgements

Susan Finger was another project advisor. Other participants were James Casazza, Patrick Choi, Mehmet Gerceker, James Grace, Gerard Hamel, Kenneth Herman, C. Kampman Lasater, Anna Li, Daniel Patterson, Seng Tek Sing, Chee Wan Teng, Louis Trebaol, Brandon Weber and Fei Lung Wong. This material is based upon work supported by the National Science Foundation under Grant No. 0205266 and the Pennsylvania Infrastructure Technology Alliance grant.

References

[1] A. Schmidt and K.Van Laerhoven. "How to Build Smart Appliances?" *IEEE Personal Communications*, Aug. 2001, pp. 66 - 71.

[2] A. Smailagic and D. Siewiorek. "Application Design for Wearable and Context-Aware Computers," IEEE Pervasive Computing, Vol 1, No. 4, December 2002, pp. 20 – 29.

[3] H. Lieberman and T. Selker, "Out of Context: Computer Systems That Adapt To, and Learn From Context," *IBM Systems Journal,* No. 3 & 4, 617632, 2000.

[4] A. Schmidt, *et al*, "Advanced interaction in context," Proc. of *Intl. Workshop on Handheld and Ubiquitous Computing,* Num 1707 LNCS, Heidelberg, Germany, 1999.

[5] S. Hudson et al., "Modeling user behavior: Predicting human interruptibility with sensors: a Wizard of Oz feasibility study," Proc. Conference on Human Factors in Computing Systems, ACM Press, April 2003, pp. 257-264.

Proceedings of the Seventh IEEE International Symposium on Wearable Computers (ISWC'03)
1530-0811/03 $ 17.00