MITes: Wireless Portable Sensors for Studying Behavior

Emmanuel Munguia Tapia, Natalia Marmasse, Stephen S. Intille, Kent Larson

Massachusetts Institute of Technology
One Cambridge Center, 4FL
Cambridge, MA 02142 USA
{emunguia, nmarmas, intille, kll}@mit.edu

ABSTRACT

We present MITes (MIT Environmental Sensors): a portable kit of ubiquitous wireless sensing devices for real-time data collection of human activities in natural settings. The sensors designed to be used in two ways: (1) determining people's interaction with objects in the environment, and (2) measuring acceleration on different parts of the body. The sensors have been designed to permit low-cost research studies where data is acquired simultaneously from hundreds of objects in an environment and multiple parts of the body.

Keywords

Wireless sensors, ubiquitous, natural settings, behavior.

INTRODUCTION

In order to study human activities and behavior in natural settings such as the home, a portable sensing infrastructure that can be easily retrofitted in existing homes and that can cope with the complexity of everyday life is required. Based on previous lessons learned from deploying large numbers of diverse sensors in multiple homes [1], we have created MITes: a new generation of portable wireless sensors that can be used to collect data on people's activities in natural settings. The following lessons learned [2] have been incorporated: (1) a single contact point is used to speed up installation and minimize chances of damage or dislodgement, (2) data from many sensors is synchronized at the reception point with wireless transmission, (3) acceleration is used to measure interaction with most everyday objects, (4) sensors can be placed in a home inconspicuously, and (5) sensors are wireless to enable real-time applications.

MITes differ from existing wireless sensor network technologies such as the Berkeley Motes and Smart-Its [3,4] in the following ways. (1) Cost: The cost of MITes with accelerometers is less than 1/3 of the cost of the least expensive commercial mote with no sensors included, even when MITes are manufactured in low quantities (<100). (2) Size: MITes are smaller since they do not require snap-in sensor boards or battery packs, which complicates installation in natural settings. (3) Complexity: due to their Tx/Rx ranges (~30m indoors and 220m outdoors) it is possible to transmit data to a single receiver without the overhead and complexity of a network infrastructure and associated OS, reducing possible failure points. (4) Frequency: MITes operate at 2.4GHz, enabling the use of an inexpensive onboard microstrip antenna of only 3cm. The newest version of the Intel mote (iMote) [5] operates at 2.4GHz and is similar in size to the MITes. However, it requires snap-on expansion boards for both battery and external sensors. Furthermore, its current unavailability and prototype price is prohibitive for deploying large numbers of sensors in natural settings.

GENERAL DESCRIPTION

The MITes wireless sensors are designed around the nRF24E1 chip manufactured by Nordic VLSI Semiconductors. The nRF24E1 integrates a transceiver, an 8051 based microcontroller running at 16Mhz, a 9 input 12-bit analog to digital converter, and miscellaneous peripherals (3 timers, UART, SPI, PWM, and 11 IO pins). The transceiver operates in the 2.4GHz ISM band (available worldwide without a special license), offers data rates up to 1Mbps, and provides 125 Tx/Rx channels for multi-channel communication. It also offers low power consumption operation such as shock burst and sleep mode and low Tx/Rx power consumptions of 10.5mA at -5dBm and 18mA at 250 Kb/s respectively. Finally, its cost is $6 per unit or $3 in quantities of 10,000 units. The chip uses a proprietary protocol that does not interfere with 802.11 or Bluetooth, which for the MITes has been confirmed in practice.

The MITes also include an external 4K EEPROM program memory, ADXL202/210 accelerometers and a 50 ohm antenna matching circuit between the nRF24E1 RF I/O and the onboard microstrip antenna. The sensors are powered by a single CR2032 coin battery.

To achieve low power consumption and extended battery life, the microcontroller and associated circuitry are kept in sleep mode whenever possible. When the acceleration signal needs to be sampled, the microcontroller wakes up, turns on the accelerometers, reads a sample, transmits the data, turns off the accelerometer, and returns to sleep mode.

STICK-ON STATE-CHANGE MITes

The core element of our portable kit is a set of sensors designed to be "stick-on and forget" devices that measure 2-axis of acceleration. They can be attached to almost any physically manipulated object in the environment such as windows, doors, cabinets, drawers, appliances and even small containers. In addition to detecting movement of objects with mechanical open-close states, they can detect directional movement in carried objects such as a remote control, pushed objects such as a chair, or vibrated objects such as a bed or couch cushion. In summary, the sensors measure characteristics of sudden movement of physical objects in the environment.

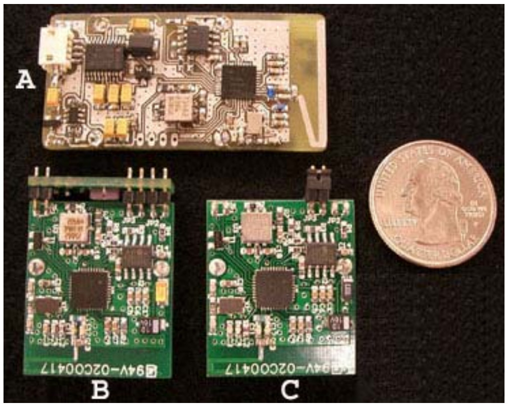

Figure 1. MITes: (A) receiver, (B) wearable accelerometer (3 axis, 10g), and (C) stick-on state-change (2 axis, 2g).

In their current form, the sensors broadcast their ID whenever a dynamic change in acceleration has reached a specified sensitivity threshold. The dynamic change in acceleration is calculated with a running average over the past six samples that is subtracted from the original acceleration. The absolute value of the resulting signal is compared with the sensitivity threshold to decide if the sensor ID should be broadcast.

All state-change MITes operate in the same Tx/Rx channel working under the assumption that the probability of collision is low. Prior work has shown this “featherweight” networking to be viable in practice [6]. Preliminary results show that a sampling rate of 10-30 Hz is necessary to measure the small movements involved in manipulating everyday objects. Thus, the sensors currently measure a range of ±2g at 10Hz. The expected battery life is at least 6 months considering the sensor is activated 40 times everyday at the highest Tx output power, running from a CR2032 coin battery. The cost for a single prototype is currently $26.20 in quantities of 80.

WEARABLE ACCELEROMETER MITes

Mobile MITes consist of the same board as the state-change MITes, but with a ±10g accelerometer instead of the ±2g one, and an extra side daughter board to provide the third axis of acceleration. They can be placed on different parts of the body to measure acceleration.

To the best of our knowledge, mobile MITes are the smallest, lightest, and least expensive wireless 3-axis accelerometer sensors available to the research community. Their dimension (1.2x1.0 x0.25in), and weight (8.1g including battery) permit them to be embedded or attached to wearable objects, such as watches, shoes or belts, without constraining the wearer’s movements.

The cost of a single prototype is currently only $41.20, and the average battery life at a sampling frequency of 200Hz is 20.5 hours at the lowest Tx power and running from a CR2032 coin battery. This enables a day of continuous data collection without replacing batteries. The sampling rate could be decreased to extend battery life if required.

Currently, it is possible to receive acceleration data from six mobile MITes simultaneously, each transmitting on a different channel. However, it is be possible to extend this to up to 125 mobile MITes simultaneously.

RECEIVER MITes

The MITes receiver interfaces with the RS232 serial port of any PC, laptop, or PDA. It includes a RF24E1 MCU+transceiver, a RS232 level converter (MAX3218) and a voltage regulator (MAX8880) for external power supplies between +3.5 and +12v. The receiver can measure 2-axis acceleration or 3 axes with an attached daughter board. It consumes an average of 28 mA and the expected battery life is approximately 50 hrs if running from three 1.2v 1400mA NiMH batteries connected in series.

CONCLUSION

Due to their advantages in cost, size, ease of use, and installation, MITes can be used in a variety of applications including research in activity recognition, balance and equilibrium, fall detection in elderly, gait defects, security systems, position tracking, interactive games, context-aware computing and human computer interfaces.

REFERENCES

1. S. S. Intille, E. Munguia Tapia, J. Rondoni, J. Beaudin, C. Kukla, S. Agarwal, L. Bao, and K. Larson, "Tools for studying behavior and technology in natural settings," in Proceedings of UbiComp 2003: Ubiquitous Computing, Berlin Heidelberg: Springer, 2003, pp. 157-174.
2. J. Beaudin, S. Intille, and E. Munguia Tapia. Lessons Learned Using Ubiquitous Sensors for Data Collection in Real Homes. Proceedings of Extended Abstracts: CHI 2004 Connect: Conference on Human Factors in Computing Systems, ACM Press, April, 2004.
3. S. Hollar. COTS Dust. Ph.D. thesis, University of California, Berkeley, 2001.
4. O. Kasten and M. Langheinrich. “First experiences with bluetooth in the Smart-Its distributed sensor network”. Workshop on Ubiquitous Computing and Communications, PACT 2001, Barcelona, Spain, September 2001.
5. Kling, R. “Intel Mote: An Enhanced Sensor Network Node”. Proceedings of the International Workshop on Advanced Sensors, Keio, Japan, November 2003.
6. M. Feldmeier, M. Malinowski, and J. A. Paradiso, "Large group musical interaction using disposable wireless motion sensors," in Proceedings of the ICMC 2002 Conference. San Francisco, CA, 2002, pp. 83-87.