Demo Abstract: SNORES: Towards a Less Intrusive Home Sleep Monitoring System using Wireless Sensor Networks

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Abstract

In modern society, a large portion of the population suffers from sleep disorder. Some sleep disorders are serious enough to interfere with functioning of daily lives. Therefore knowing how well one sleeps is an important health indicator that can lead to more aggressive actions. In this demo, we present *SNORES: Sensor Networks Oriented REsearch in Sleep*. SNORES is an in-home sleep monitoring system that is inexpensive, easy-to-install, and less intrusive.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Wireless communication; C.3 [**Special-Purpose and Application-Based Systems**]: Real-time and Embedded Systems; H.4 [**Information Systems Applications**]: Miscellaneous

General Terms

Experimentation

Keywords

Wireless Sensor Networks, Sleep Research

1 Introduction

Although acknowledgement of one's sleep disorder is crucial for the individuals, such information is not trivially accessible in common home environment. For accurate diagnosis, people visit hospitals to have doctors conduct polysomnography(PSG) while they sleep in the PSG lab [3]. Since these methods are costly, inconvenient, and intrusive, generally only people with strong needs for immediate health care visit the hospitals.

Therefore we present SNORES, an in-home sleep monitoring system using WSN. The system provides feedback on the subject's sleep pattern and detection of sleep disorder symptoms, based on collected sensor data. Use of sensors that are far less intrusive than the current PSG in hospitals and wireless communication to gather data can reduce the intrusiveness. Low-cost system makes it possible for economic deployment in home environments. This system would be used by non-patients to monitor their sleep at home and get reliable feedback on their possible sleep disorder. Depending on the severity, the system would suggest for a visit to a hospital.

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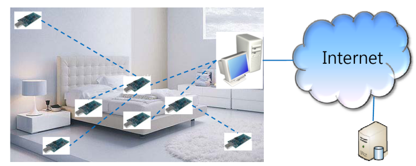

Figure 1. System Architecture

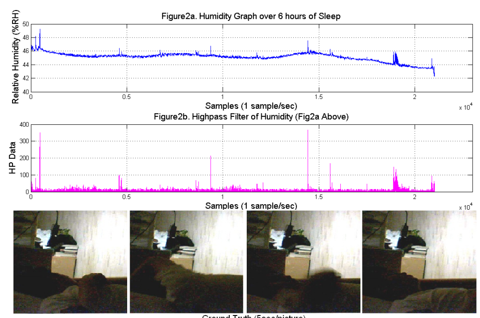

Figure 2. Humidity data

2 Architecture Overview

Figure 1 shows the overall architecture. Sensor nodes gather sensor data about the subject or the environment. Some sensor nodes are located close or on the subject to gather data. Other sensors are scattered in the room to obtain the environmental data. The data is forwarded to a gateway, and then the gateway again forwards the data through the Internet to a database server. Then the stored data can be accessed and analyzed for feedback.

3 Preliminary Results

For our experiment, TelosB [1] running TinyOS is used. Sensors are prepared for reading humidity, acceleration, temperature, and sound. Some of the related work have determined that humidity sensor is quite reliable in terms of detecting human presence [2]. With several experiments, we have verified that humidity sensor, Sensirion SHT15, can be useful in detecting the subject's movement during sleep. Also, unintentional physical touch of the sensor during the subject's movements showed great results in terms of the detection, although the system works well without the need for a physical touch. Humidity sensor was placed less than a half meter away from the subject's face. Although we will present a full networked sensor system, for simpler experi-

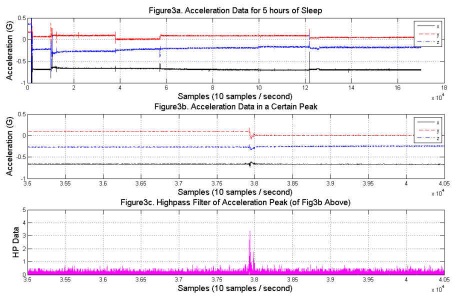

Figure 3. Acceleration data

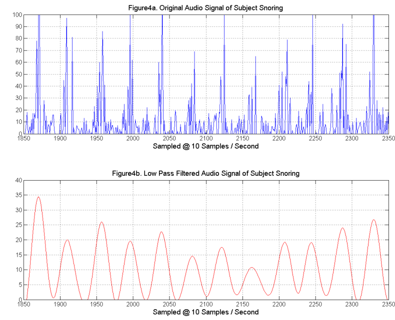

Figure 4. Audio data of Subject Snoring

ments, data were collected using a direct UART communication to the PC from a sensor node. Figure 2 shows a six-hour span of the humidity readings. Figure 2b shows the high-pass filtered data of Figure 2a, the overall humidity measurement. Please note that the sudden changes in humidity values correlate greatly with the high-pass filtered graph. The peaks of Figure 2b also correlate well with the ground truth; the subject's changes of body position. We have collected the ground truth by using a webcam with LED lighting to be able to take pictures periodically (1 picture/5 seconds). In Figure 2 the series of pictures are shown to demonstrate the ground truth, correlated by their time stamps, which indicate the subject's movement during sleep.

Humidity data however show limitations when the subject moves away from the detection range of the sensor. If the subject's movement happens at the edge of a bed, the movement cannot be detected. Therefore we have explored different sensors for the use in our application. Accelerometer proved to be outstanding in detecting subject movements during sleep. We use Analog Device's ADXL330 3-axis accelerometer. Figure 3a indicates the overall acceleration data collected about 5 hours of the subject's sleep when the accelerometer was located on one side of the bed. Figure 3b and 3c indicate a certain peak of the acceleration data. Our experiments have shown that placing multiple accelerometers in different locations yields in better detection results. With these results we will demonstrate the sensor placement under the pillow and on each side of the subject.

We have also experimented using an audio sensor, a FK648 condensor microphone from Future Electronics. The audio sensor can be a great measure for detecting some of subject's sleep disorder such as snoring and grinding of teeth. Using this device, we were able to capture a subject's snoring pattern. This is shown in Figure 4. To fit the purpose of our application and the limitations of our hardware, we sampled at 10 samples/second; a relatively slow rate for audio signals. Although under-sampled, a clear pattern can be observed from the raw audio signal. The signal was passed through a Butterworth IIR filter of order 5 to denoise the signal. This allowed the system to accurately capture the snoring pattern of the subject.

4 Discussion and Demo

We have divided our project into two different sectors depending on the deliverables. First deliverable is the non-intrusiveness. To demo this, we designed a system with no physical contact to the subject. As shown from the preliminary results section, using humidity, acceleration and audio sensors can detect some of sleep disorders such as the subject's frequent changes in body position, twitches, hypnic jerks, snoring, and teeth grinding. To overcome false detection, the system will verify by cross referencing with multiple sensors. Second deliverable is providing less intrusiveness with higher reliabilities. This may be used for more accurate analysis of the subject's sleep disorder. For such requirements, we are currently investigating a means to detect breathing related disorders, such as sleep apnea by using less number of sensors in a less intrusive manner than the current PSG system.

During the demo, the system will present its ability to infer sleeping pattern and to detect various sleep disorder symptoms using sensors in a network. The demo environment will consist of a mattress and a pillow that resembles the actual sleeping environment. Several TelosB sensor nodes, outfitted with temperature, humidity, acceleromter, CO2, and audio sensors, will be deployed on the mattress. Each sensor node will transmit calibrated sensor data to a base station node using a network stack to enable efficient communication. An experimenter will simulate various sleeping disorder symptoms. At the end of experiment session, the result feedback will be presented.

For more information, please visit the project website at *www.irisen.org/SNORES*.

5 References

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