A Dynamic User Posture Inference Scheme for Mobile Devices

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ABSTRACT
A dynamic user context inference method is one of the important technologies for realizing context-aware services. In this paper, we show a context inference scheme that realizes a user posture inference with only one acceleration sensor embedded in a mobile handset. To improve inference accuracy, the system automatically detects the sensor position on the user's body and dynamically selects the most relevant inference method. Our experimental results show that the system can infer a user’s posture (sitting, standing, walking, and running) with an accuracy of more than 96%.

Keywords
Context-aware computing, Ubiquitous computing, User posture inference, Acceleration Sensor

1. INTRODUCTION
User context awareness is one of the important concepts for application services in the ubiquitous computing environment. In general, user context means user's posture, movement, situation, emotion, preference, etc. In our previous research titled "CoCo," we explored feasibilities of a context-aware service that monitors users' context with a set of off-the-shelf worn sensors and delivers the most appropriate contents based on the users' objective, preference, location, and context [1]. During our research, we have noticed the importance of a practical and reliable context inference method within the mobile environment.

A mobile phone is one of the attractive devices as a context inference sensor because it is equipped with computation and communication capability and always carried by users. Some researchers explored user activity inference methods with a mobile handset[2]. They assumed that the sensor position on the body is fixed (e.g. in hand, in the pocket). However, according to a survey on the usage of mobile phone, 77.6% of respondents always put their mobile phones in a bag, pants pocket or chest pocket, and 13.2% of people change the mobile phone position from day to day. Thus, a context inference method needs to adapt to at least these three positions and frequent change of the position.

In this paper we show a user posture inference scheme that supports different sensor positions on the user’s body. Our inference method requires only one 3-axis acceleration sensor embedded in a mobile handset. The system automatically recognizes the sensor position on the user's body and dynamically selects the most relevant inference method.

2. SYSTEM ARCHITECTURE
As a prototype system, we attach a sensor node (Pavenet module [3]) with 3-axis acceleration sensor (LIS3L02DQ) on a cell phone shell. The acceleration sensor data is transmitted to a mobile PC via Bluetooth. The sampling rate of each axis sensor data is 20Hz. The actual analysis of acceleration sensor data is processed on the PC. Figure 1 summarizes our inference system architecture.

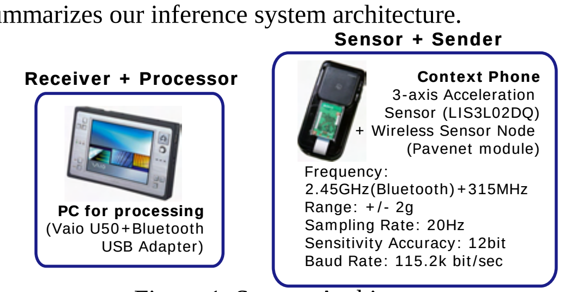

Figure 1. System Architecture

3. CONTEXT INFERENCE
We divide our inference method into three steps. The first step is pre-processing. Feature values are extracted from the acceleration data. The second step is sensor position inference. The system infers where the mobile phone is placed on to select the right posture inference scheme. The last step is user posture inference. The system recognizes the user's posture using an algorithm based on the sensor position.

Pre-Processing
The system calculates the variance for the last 12 samples, the average of each axis for the last 4 samples, the maximum value of the FFT power spectrum for continuous

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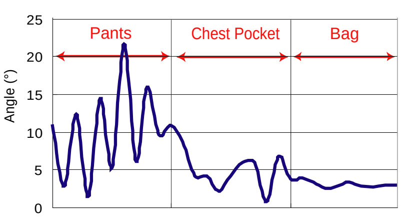
64 samples, and the change of the angle of the sensor device. The sensor angle is calculated by detecting the present gravity vector.

Sensor Position Inference

We infer the sensor position by the following three criteria.

- When a user doesn't wear the sensor device, the variance is nearly 0.
- As Figure 2 indicates, when the sensor device is in the pants pocket, the sensor angle fluctuates when the user walks.
- As Figure 3 indicates, when the sensor device is in the chest pocket, the sensor data shows a unique change when the user leans forward while sitting down.



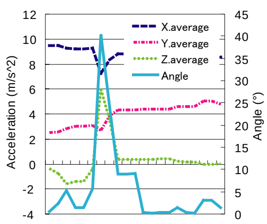


Figure 2. Result of Angle change   Figure 3. Sitting motion

User Posture Inference

When the sensor device position has been determined by the previous operation, the system selects the relevant algorithm to infer the user's posture.

Firstly, we describe two general rules. These rules are used regardless of the device position.

- Use the variance value to determine whether the user is moving or not.
- Use the maximum value of the FFT power spectrum to determine the state of running, walking and the pace of running.

Secondly, we describe two specific rules based on the sensor device position.

- As Figure 4 indicates, when the sensor device is in the pants pocket, a change of the sensor angle can be used to estimate the sitting motion.
- When the device is in the chest pocket, the sensor angle is helpful in estimating forward-leaning, backward-leaning, or side-leaning.

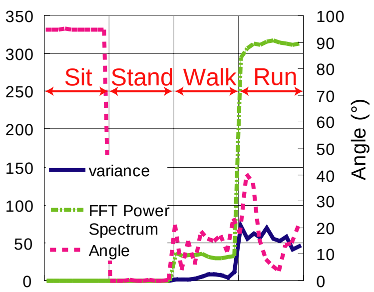


Figure 4. Result of Posture Inference in pants pocket

Figure 5 shows our inference scheme.

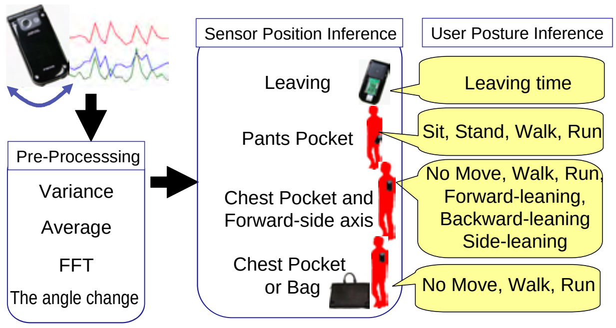


Figure 5. Inference Scheme

4. EXPERIMENTS

We conducted an evaluation experiment on four subjects. The subjects are asked to place the sensor device in three positions (pants pocket, chest pocket, and bag). Then they repeat four postures (sitting, standing, walking, and running) for 20 seconds for a total of about 10 minutes. In the experiment each person used the bag he/she usually uses. The results of the posture and device position inference are shown on Table 1. The results show that we can realize the inference with high accuracy.

	sitting	standing	walking	running	Device position
Pants	100%(675/675)	100%(675/675)	97.8%(660/675)	96.7%(653/675)	98.3%(2654/2700)
Bag	99.7%(718/720)		98.8%(711/720)	98.2%(707/720)	98.7%(2131/2160)
Chest	99.7%(718/720)		99.9%(719/720)	98.9%(712/720)	97.4%(2103/2160)

Table 1. Result of Posture and Device Position Inference

5. CONCLUSION AND FUTURE WORKS

In this paper, we presented a user posture inference method using a single 3-axis acceleration sensor. The system automatically detects the sensor position on the user's body and dynamically selects the most relevant inference method.

We are currently working on developing a context-aware application using this inference method.

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