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Design and Implementation of a Sensor Management Device for Wearable Computing

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Abstract

In wearable computing environments, a wearable computer runs various applications with various sensors (wearable sensors). Since conventional wearable systems do not manage the power supply flexibly, they consume excess power for unused sensors. Additionally, sensors frequently become unstable for several reasons such as sensor breakdown. It is difficult for application engineers to detect the instability. To solve these problems, we have developed a new sensor management device called CLAD (Cross-Linkage for Assembled Devices) that has various functions for power management and sensed data management. CLAD improves data accuracy and operational reliability.

1. Introduction

Recently, because of computer downsizing, wearable computing is attracting a great deal of attention. Wearable computing has the following three features compared to conventional computing, (1) Handsfree, (2) Power is always on, (3) Enhances people's daily lives[1]. With wearable sensors, wearable computers provide various services such as navigation, health care, and context-aware systems[2].

Conventional systems using multiple sensors have several problems. For example, a navigation system using GPS, accelerometer, and gyro sensor to acquire position[3] has high accuracy but heavy power consumption because it uses all sensors at all times. However, GPS is unavailable indoors, and sensors frequently become unstable because of breakdowns, power shortages, overcurrents and so on. It is difficult to detect the instability from only the sensed data.

To solve these problems, we have developed a new sensor management device called CLAD (Cross-Linkage for Assembled Devices) that has various functions for power management and sensing data management.

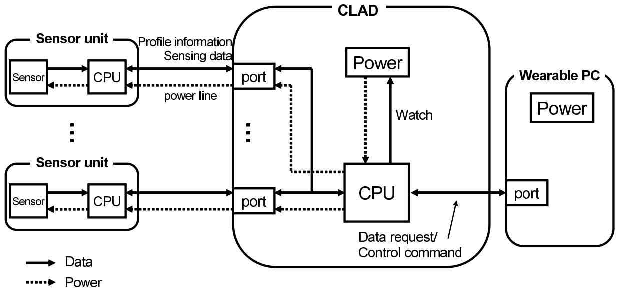

Figure 1. System structure of CLAD

2. System Design

In wearable environments, though a computer is always on, sensing is not always required. A user can equip multiple kinds of sensors, which consumes a lot of power. CLAD is placed between the wearable computer and wearable sensors, and it manages sensors to enable (1) flexible power-supply control to save energy, (2) flexible error control to achieve sensing accuracy and hardware error recovery.

2.1. System structure

Figure 1 shows the system structure of CLAD. CLAD has its own power source and manages sensors connected to it. Moreover, it monitors the voltage and current to detect power shortages and overcurrents. Each sensor unit has its own information about one sensor's type, accuracy, output range, start-up time, operating voltage, and operating current. Each unit has a CPU to hold this information and answer CLAD's calls.

Table 1 shows the control commands for CLAD. Table 1(a) shows the control commands from CLAD to sensors for managing power control and sensing data requests, Table 1(b) shows the commands from CLAD to PC for notifying CLAD status, and Table 1(c) shows the commands

Table 1. Command tables

(a)Sensor control command

Command
Power off
Sensing data request
Profile request
Power on

(b)PC control command

Command
Overvoltage
Overcurrent
Data anomaly
Sensor anomaly
CLAD Startup
CLAD End

(c)CLAD control command

Command	
Pseudo data generation	On
	Off
Filtering	On
	Off
Data merging	On
	Off
Change importance	High
	Low
Change criteria	Importance
	Rareness
	Power consumption
	Accuracy
	Startup time
Power supply	Start
	Stop
Sensing	Start
	Stop
Profile information request	
CLAD end	

from PC to CLAD for controlling CLAD functions. When a new sensor is attached to CLAD, it sends profile information to CLAD. Then, CLAD sends commands to the sensor for controlling it based on requests from the PC. When CLAD detects sensor errors or other troubles, it sends an alert to the PC and addresses them.

2.2. CLAD function

The functions of CLAD are divided into power management and data management. The features contributing to each function are shown in Table 2.

2.2.1 Power management

Alternative device retrieval and changeover

CLAD detects sensor anomalies from consecutive outlying data or sensor disconnections, etc. In such cases, CLAD refers to profile information and uses an alternative devices if they exsit.

Power saving

CLAD always monitors the internal power source. In

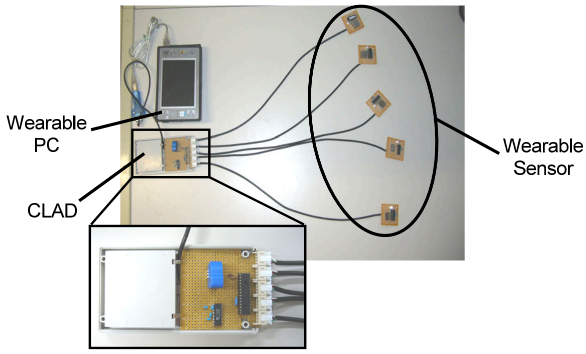

Figure 2. CLAD prototype

case of a power shortage, it cuts down on power consumption by stopping the power supply to part of the sensors according to a refusal policy.

Overcurrent detection

When detecting an overcurrent, CLAD stops all power supplies for safety.

2.2.2 Data management

Filtering

When sensed data is outlying based on the profile information, the data is automatically filtered.

Data merging

When the same kind of multiple sensors are attached to CLAD, it merges their data to improve accuracy.

Pseudo data generation

If CLAD finds no alternative device during alternative device retrieval, it generates pseudo data. The pseudo data is generated from learned data or relationships to other sensors' data. This function improves a operational reliability.

Error detection

CLAD detects errors and uses alternative devices or generates pseudo data. Additionally, since CLAD notifies the PC of these errors, applications can deal with the errors individually such as by displaying a message to induce a battery change.

3. Implementation

We implemented a CLAD prototype using a Microchip PIC16F873A as a processing unit. We implemented the system software on a Microchip MPLAB using CCS PIC C Compiler. The CLAD prototype and wearable sensors are shown in Figure 2. Table 3 shows the specifications of the prototype. Each wearable sensor has a processing unit that carries out communication control. CLAD measures the power source voltage using a Zener diode, and we use a

Table 2. Features of CLAD

Feature \ Function	Power managemet			Data management			
	Alternative device	Power save	Overcurrent detection	Pseudo data	Error detection	Filtering	Data merging
Power control	○	○	○				
Profile information	○	○		○	○	○	○
Voltage check		○		○	○		
Current check			○		○		
Sensing data management				○	○		

Table 3. CLAD specifications

Connection method		RS232C
Power source		4 dry batteries (AA)
Communication speed		9600 bps (Max.)
Size(main body)		W 76 × H 13 × D 70 mm
Weight	Without battery and cable	130 g
	With battery and cable	292 g
Power consumption		0.05 W

Current Transducer LTS6-NP by LEM for current monitoring.

Figure 4 shows the power saving function of CLAD. Using five accelerometers, there are two lines in the graph, that indicating the power consumptions using CLAD and not using it. The power consumption does not change without CLAD because all sensors are always active. In contrast, CLAD decreases the power consumption by changing the number of active sensors.

4. Consideration

As an example of how CLAD is used, we consider a locating system using GPS, accelerometer, and gyro. GPS is not able to get information indoors and makes accidental errors. An accelerometer and a gyro sensor are able to detect users' actions in detail, but errors accumulate as we use them. CLAD automatically adapts to the situation.

Many context-aware systems employ probability-based matching with multiple accelerometers. If the amount of input data decreases due to sensor breakdown, cognitive accuracy drops off. We implemented a context-aware system using CLAD and evaluated cognitive accuracy with pseudo-data. We used 5 accelerometers and dropped them out in all combinations (31 patterns). The result shows that the use of pseudo-data achieves higher accuracy compared with not using pseudo-data (average improvement 7.46%).

In related work, Personal Mobile Hub[4] serves as the focal point for all devices worn by the user. Since it supports multiple wireless protocols, devices that have different protocols can communicate. It however does not work for problems such as power shortages or exothermic heat. Therefore, the hub serves only as a router and gateway.

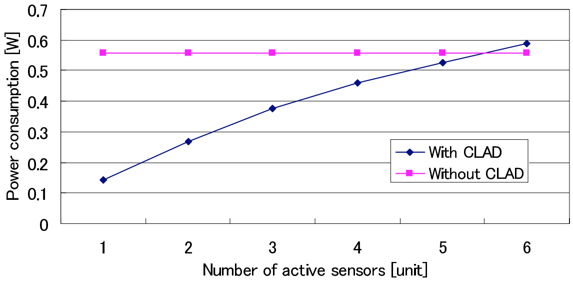

Figure 3. Active sensors vs. power consumption

5. Conclusion

We have designed and implemented CLAD, which is a management device for wearable sensors. CLAD saves power by dynamically managing sensor power and achieves high data reliability through management of sensed data and error control. It was clear from the evaluation experiment that CLAD saves power. By having sensors dynamically cover defects with each other, CLAD improves power efficiency and operational reliability.

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