

A Monitoring System of Human's Health Using Wireless Sensors

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ABSTRACT:

Healthcare monitoring for elderly people has recently been paid much attention in many countries with long life expectancy. Wireless sensors attached to a human body are considered useful in automating the healthcare monitoring process. We propose a system of such a monitoring system called Always-on Karte. In contrast to previous works, our design goals are focused on "unconscious" monitoring and continuous analysis. To reduce the energy consumption caused by wireless data transmission and consider wireless connectivity, the wireless sensors conduct adaptive reporting; the transmission is determined based on the perceived state. As an embodied object of Always-on Karte, we have developed an AoK mule. The AoK mule consists of tiny pressure sensors connected with MicaZ Motes and aims at analyzing the soundness of walking actions. In this paper, we describe the preliminary result using the AoK mule and future visions.

INTRODUCTION

With the advent of a growing aging population in many countries including Japan with long life expectancy and low birth rate, technology is needed to monitor the health of elderly people at home. The diagnosis of the health condition is not simple because self-monitoring without medical specialists may cause misjudgment. To assist such diagnosis, there are several trials by several companies to conduct such monitoring using a home sensor network [5].

Based on the above background, we propose a system of monitoring human's health condition called Always-on Karte. ("Karte" is originally a German word and is being used as a word for a diagnosis sheet described by medical doctors in Japan.) In contrast to conventional works, Always-on Karte sets two goals: "unconscious" monitoring and continuous analysis.

- (1) unconscious monitoring: People may feel reluctant to wear a monitoring equipment. Even if a person agrees with wearing the equipment, he/she may sometimes forget to re-wear it. Thus we base our design on using objects not conceived as monitoring equipment.

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- (2) continuous analysis: Instead of creating reports of a person's health state at some interval such as daily or several times per day, Always-on Karte continuously makes a log of the person. This results in a challenge in creating an efficient database, but it enables a fine-grained trace of the person's state and analysis of the person's daily life pattern.

The communication between a sensing transmitter attached to a person's body and a receiver is required to be efficient. We take two factors into consideration for the communication: the perceived state of the person and the wireless connectivity. Instead of always transmitting raw sensed data, the sensing transmitter only sends a summarized state when the perceived state does not change significantly. In addition, data is not transmitted but stored locally inside the transmitter while the communication link is unstable.

As an embodied example of Always-on Karte, we have developed a prototype, an AoK mule. The AoK mule consists of multiple tiny pressure sensors on the mule and MicaZ Motes. Our FFT analysis shows that a person's walking tendency can be extracted using the AoK mule.

The rest of the paper is organized as follows: Section 2 gives the design of Always-on Karte. Section 3 describes the prototype of Always-on Karte. And section 4 describes the results experiment. Sections 5 and 6 present related work and conclusion, respectively.

DESIGN

This section describes the basic design of Always-on Karte and the AoK mule.

Architecture

The system of Always-on Karte consists of AoK probes, AoK recipients, and AoK server (Figure 1). AoK probes are the devices that collect data from a human and they are equipped with a wireless communication link. One person may wear multiple AoK probes and they may communicate with each other.

However, we do not necessarily assume formation of a network using the AoK probes. AoK recipients constitute a network inside a home for transferring data collected from an AoK probe. Within the network, the AoK server exists and maintains a database called Karte. The AoK servers is also connected to an outgoing network and enables transmitting the Karte to a doctor and accepting inquiry regarding the Karte from a family member of the person who lives at a distant place.

The devices that do not compel the person to wear are chosen as AoK probes. For instance, wrist watches may not be suitable for AoK probes, but eyeglasses with tiny vibration sensors can be AoK probes for those who wear eyeglasses in the daily life.

What to sense

AoK probes continuously collect values of physical variables such as acceleration, temperature, and pressure. We call these values "raw data." Although fine-grained raw data is important in many cases, we are more interested in the behavior of the person to identify the healthiness of the person. We call these analyzed and classified behavior "personal state." The values of the personal state includes "walking normally", "walking irregularly", "sitting", "cooking", "eating" and "brushing teeth." By adding various types of AoK probes, the possibility of finer classification of the state increases.

Storage and transmission

AoK probes are equipped with their own local storage. Raw data is continuously stored into the local storage. The personal state is simultaneously calculated using the raw data. If

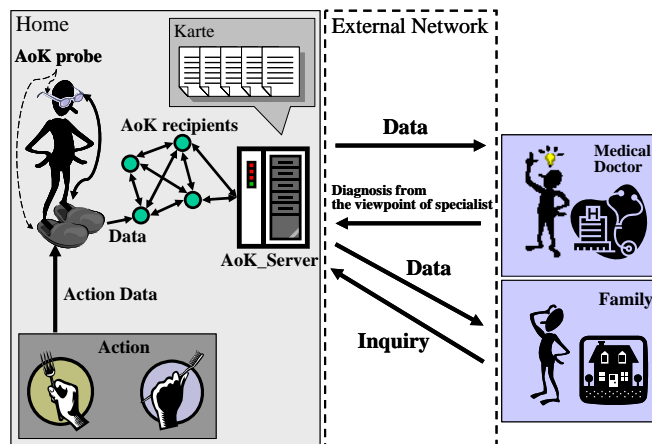


Figure 1: Our System

we hypothesize huge amount of memory and an always-connected communication channel, we do not have engineering problems. Since we cannot base our design on the above hypothesis, the tradeoff between storage and transmission is required. To attain the good tradeoff, we take the following policy.

- Raw data which are older than a predefined threshold value for not overflowing the local storage is discarded
- If quality of the communication channel between the AoK probe and its nearby AoK recipient is significantly low or the AoK probe cannot find an AoK recipient, the data transmission is suspended.
- During the suspension of the communication, raw data is continuously collected. However, the personal state derived from the raw data does not change significantly, the newly acquired raw data is discarded.
- If the suspension of the communication lasts long and the local storage overflows, the past personal state is compressed.
- Once the connection resumes, the personal state remaining in the storage is sent first, and subsequently the stored raw data is sent.
- If the communication channel is retained but the quality of the channel is low, only the personal state is sent.

Although the above is the basic policy, we assume an environment where disconnection does not occur frequently.

AoK mule

As the first implementation of an AoK probe, we have chosen a mule. Mules themselves are not monitoring equipment and people do not feel that they are monitored. The ultimate goal of the AoK mule is analyzing the frequency of a person's movement inside a home and the soundness of walking of the person. Figure 2 shows architecture of AoK mule. The AoK mule acquires personal data from sensor and sends the data to AoK_Server through wireless network. A local analyzer is used to arrange the data using analysis of personal data. The data received from the AoK mule are stored in the database of AoK_Server. The personal data are sent to medical doctor and person's family through external networks. The Karte received from medical doctor is stored in the database.

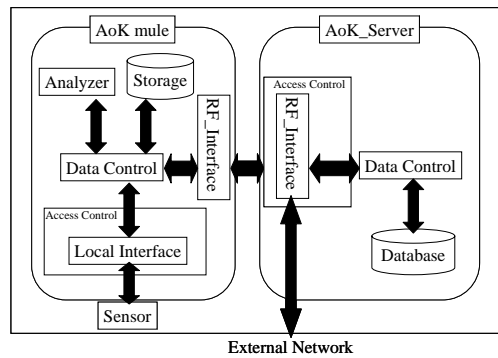


Figure 2: Architecture of AoK mule

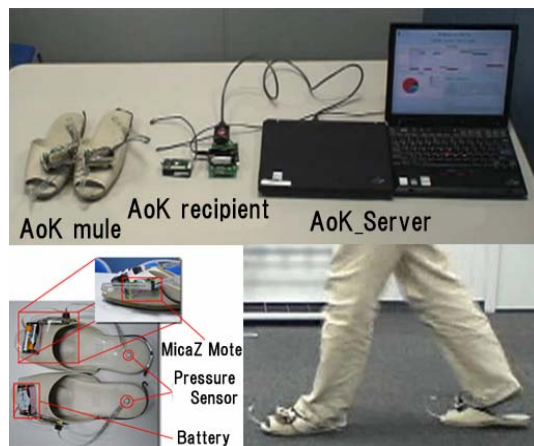


Figure 3: Components of our system

PROTOTYPE

We have implemented a prototype of AoK mule. In this prototype, we focus on collecting the distribution of pressure and exploring the feasibility of acquiring higher-level information about the state of a person. Therefore, the function of creating summarized states is not included in the mule; signal processing is performed at the AoK_Server for feasibility study. The hardware of the AoK mule consists of a mule, MicaZ Motes[4], and three pressure sensors on the surface of the mule. The output signal of the pressure sensor is connected to the Mote and converted to digital data. By installing three pressure sensors on the surface, the distribution of the pressure can be observed. Figure 3 shows the prototype system. As seen in Figure 3, the pressure sensors are put onto the forefront and the back on the surface. The digitized pressure information is sent to an AoK_Server via wireless communication of the Motes.

EXPERIMENT

A preliminary experiment was conducted. A person for this experiment wore a pair of the AoK mule in his both feet. We measured the pressure values at six points while he was walking for 60 minutes. The collected data which were sent from the mule to a server computer were analyzed to classify the personal state into the following three categories.

- Normal walking
- Shuffle walking
- Forward-bending walking

Shuffle and forward-bending walking may lead to high risk of stumbling. Therefore identifying these kinds of walking still provide symptoms for unhealthiness.

Figure 4 shows the temporal change of the pressure for the three types. As seen in the graph, the variation in the sensed pressure is large and the peaks for the front part and the rear part appear alternately in normal walking. This is reasonable because of the nature of walking. In contrast, the peaks at the rear part indicate much larger than those at the front part in shuffle walking. As expected, the peaks at the front part indicate much larger than those at the rear part in forward-bending walking. Through the whole experiment, the values at the middle point remained significantly small. However, it will be useful to detect anomalies of a flat-footed person.

Next we performed FFT analysis for the acquired pressure data. Figure 5 shows the results of frequency spectrum for the three types of walking. The case for normal walking clearly differs from other cases; it exhibits a peak at near 10 Hz. The shuffle walking case exhibits a peak at near 40 Hz and 1 Hz. In addition, the forward-bending walking case exhibits a peak at near 15 Hz and 1 Hz.

Based on the above preliminary analysis, we are planning to implement an analyzer of the personal state particularly focusing on the type of walking into the AoK mule.

RELATED WORKS

In the CodeBlue project[6] by V.Shnayder et al. they propose emergency medical service in healthcare management by using radio transmission sensor devices. The used sensor is a MicaZ Mote with a pulse type oxygen analyzer or an electrocardiogram sensor. It is attached to a person's finger or body and captured person state, is sent through radio transmission. This system requires explicit attachment of sensors to a body. Our system is characterized by unconsciousness. Therefore, mental burden to elderly people is little. In addition, our system assumes using empowered daily objects, and a person's daily life pattern.

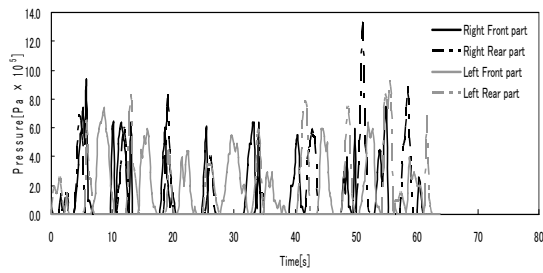
Nike+ iPod [3] allows the runner to receive audible updates on the speed at which he/she is running, distance and calories burnt upon request. Wireless sensor which is inserted in Nike+ shoes sends information to iPod. iPod which attaches receiver displays information. Adidas 1[1] measures compression force, when a user's foot hits the ground. In addition, Adidas 1 adjusts cushion at the heel. Adidas 1 includes a microprocessor and sensors. These systems only collect value of physical variables. An AoK mule with SCE extracts Walking Context by analyzing Probe Context of both feet.

CONCLUSIONS AND FUTURE WORKS

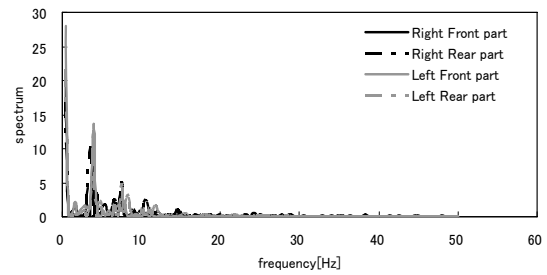
We have presented Always-on Karte, a system of a monitoring system for elderly people's healthcare using wireless sensors. In our system, as an embodied object, we have developed an AoK mule, a prototype of AoK. The AoK mule acquires the distribution of foot pressure for analyzing the soundness of walking actions. We have designed our system by considering two objectives: "unconscious" monitoring and continuous analysis. In our experiment, we have analyzed a person's walking tendency.

For our future work, first, we will investigate identification of a person. Frequency spectrum of walking depends on each individual's characteristics, thereby utilizing this information to the identifications. Second, in this experiment, we have considered types of walking. However, there are many other patterns about walking. Furthermore, we are planning to extend the coverage of the personal state.

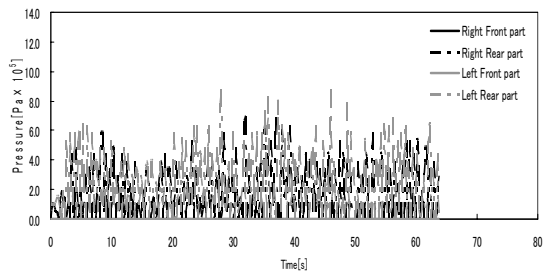
Finally, we need to consider the extent of exposing a person's behavior. If no mechanism of privacy protection is applied, the person's daily life is unnecessarily exposed to the public.



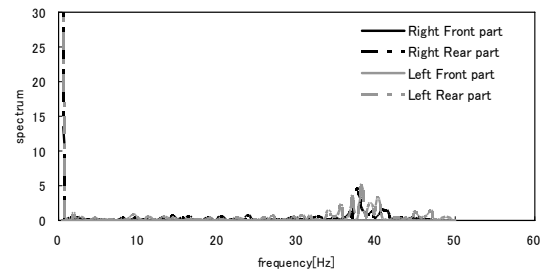
(a) Normal walking



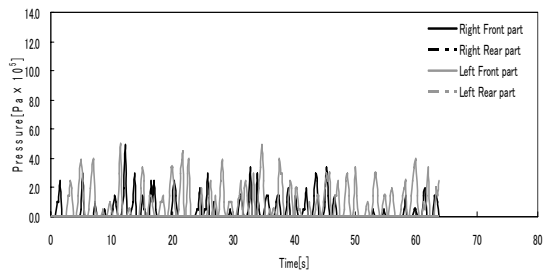
(a) Normal walking



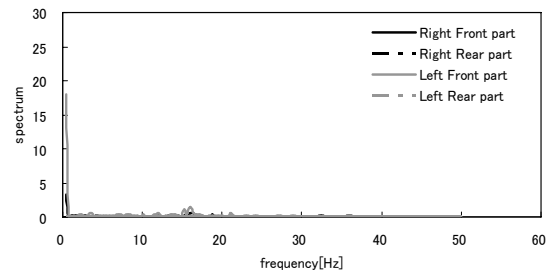
(b) Shuffle walking



(b) Shuffle walking



(c) Forward-bending walking



(c) Forward-bending walking

Figure 4: The temporal change of the pressure

Figure 5: Pattern of walking

ACKNOWLEDGEMENTS

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