사생활 보호를 위한 생체 신호기반 컨텍스트 분석 및 구분기법*

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Context categorization of physiological signal for protecting user's privacy

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Abstract

Privacy and security are latent problems in pervasive healthcare system. For the sake of protecting health monitoring information, it is necessary to classify and categorize the various contexts in terms of obfuscation. In this paper, we propose the physiological context categorization and specification methodology by exploiting data fusion network for automatic context alignment. In addition, we introduce the methodologies for making various level of physiological context on the context aware application model, which is wear-UCAM. This physiological context has several layers of context according to the level of abstraction such as user-friendly level or parametric level. This mechanism facilitates a user to restrict access to his/her monitoring results based on the level of details in context.

Keyword : Context awareness, Context categorization, Physiological signal analysis

1. Introduction

In healthcare application, the movement for making contextual information in pervasive and ubiquitous computing environments is appeared. Health monitoring involves collection of data about vital body parameters from different kinds of sensors and making decision based on them. This information is of personal and is required to be secured. In any information system it is essential to build a security mechanism in order to protect the information, as it is susceptible to breaches either when it is stored or when it is being transmitted. This communication should be confidential, because this medical information should be inaccessible to others.

In order to protect the context about health monitoring, it is necessary to classify and categorize the various contexts in terms of obfuscation. The researches on context categorization have been reported for the purpose of disclosure control in ubiquitous computing environment. However, most previous works just considered about location information as an example. In addition, they usually have utilized an ontological description which maps volume of area or location into categories of context information with reflection of hierarchy. For instance, city is in the highest level of the hierarchy, and suburb belongs to city as a sub-element of it. Building is subject to suburb and room is under building while taking 1 lower level respectively. However, this is just applicable only under the same ontology which is predefined and restricted by applications or context types. Namely, previous researchers did not indicate the way to generate the level of contextual information and its relationship.

* This work is supported by Seondo project of Ministry of Information and Communication in Korea

In this paper, we propose the physiological context categorization and specification methodology by exploiting data fusion network for automatic context alignment. In addition, we introduce the way to make various levels of physiological context. Low level of context is generated from the physiological signal sensing part and high level context is computed from context integrator module which has a role to integrate the context in wear-UCAM. Finally, several layers of contexts represent according to the level of abstraction and it is interpreted as a user-friendly level or a parametric level. The user friendly level describes analyzed results and the expert level represents measurement parameters. This mechanism facilitates a user to restrict access to his/her monitoring results based on level of details contextual information. To validate the mechanism, we have conducted experiment with wrist type physiological sensors that monitor the user's physiological states. As a prototype of our information disclosure mechanism, we developed an application which helps a user adjust the detail level of his/her physiological data disclosed to information requesters. The application includes a physiological sensor that collects physiological details of user's body condition.

The remainder of this paper is structured as follows. In section 2, we present related works. In section 3, we discuss the mechanism about context categorization with context alignment and description about level of physiological context with some procedures. In section 4, we describe the implementation on wearable physiological sensing and analyzing. Finally we present the conclusion and future works.

2. Related Works

Many research activities are underway on applying context-aware computing to personal health monitoring systems [1]. Health monitoring in out-of-hospital conditions has been of interest to researchers and healthcare practitioners for a long time. Recording of physiological variables in real-life conditions could be especially useful in management of chronic disorders or health problems; e.g., for high blood pressure, diabetes, anorexia nervosa, chronic pain, or sever obesity. Furthermore, real-life long-term monitoring of health could be useful for measurement of treatment effects at home, in situations where the subjects live their daily life [2]

In futuristic smart environments, wearable sensing can be used for monitoring various diseases, especially for elderly people and some preliminary experiments have been done. In this regard privacy and security are potential problems in pervasive healthcare. Healthcare data should be available anytime anywhere, but only to authorized persons. Pervasive healthcare information could be abused by corporations in deciding who should be promoted, by insurance companies in refusing coverage for people with poor health, and by spouses and their attorneys in divorce cases [3].All this calls for some clear guidelines on who can access such data.

In recent years, some researchers have aimed at protecting the context privacy by granting the users with details of control over the disclosure of personal contextual information [4][5]In addition, the context disclosure is subordinated to the categorization of contextual information. In previous work, the disclosure control mechanism supports the operation over different context type and multiple levels of granularity for disclosed context information [6]. Lederer et al. proposed four different levels of context information with an example of location information such as precise, approximate, vague and undisclosed [7]. In addition, Chen et al. developed the obfuscation of location information with a predefined ontology for protecting user's privacy [8].

3. Context categorization

3.1. Context categorization with data fusion network

Context categorization is a first step to resolve the ambiguity of context information. Originally, in the field of AI, there are some issues on context formatting and its categorization because AI programs suffer from a lack of generality. We describe some of the examples of context information as shown in Fig. 1.

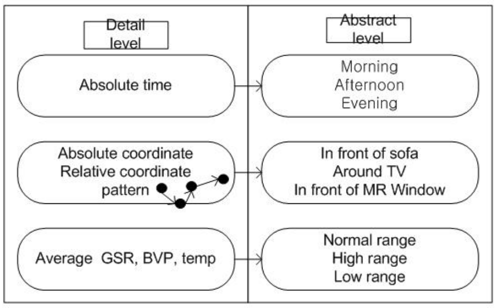


Fig. 1.Examples of Level of context

In particular, we are interested in representing different categorization with the view point of context abstraction. We assume that detailed level of context contain less information than the abstract level context referenced by V. Akman [9].

In this paper, we concentrate on the physiological context and its abstraction. The level of context is described with following Table 1. Physiological context is largely inferior to the developer. Indicators obtained from the physiological signal processing and analyzing should be verified with empirical methodologies because there exists a wide range of hypothesis about response in human body and lack of standardization in physiological signal analyzing.

Table 1. Features and characteristics of physiological context

Layman context		Expert context		
Feature	Range		Feature	Range
Entire body condition	Relative value (0~5)	PUL	Heart beat	600~1000ms
			Heart intensity	20~ 100
			$\frac{HRV\_LF\_Power}{HRV\_HF\_Power}$	1.6-2
Stress level	Relative value (0~5)	GSR	Mean	50-1000
			Transition	0~20 uohm
Emotional states	Relative value (0~5)	SKT	Mean	31~35°C
			Normalized transition	0~1

The proposed the physiological context categorization and specification methodology is exploited data fusion network for automatic context alignment. Context alignment module which gives level of contextual information based on the level of desires or request of user. Basically, it takes into account the sensor states, to decide the level of context information with the data fusion network. Data fusion network support flexible decision making step considering sensor, analysis result, other indicators and ground based information. Physical sensor is attached directly in first step, and then we get some information about sensor attribute such as sensing precision, sensing accuracy and sensing ranges. According to the sensing attribute, we preliminary compute the level of context. For example, when we assumed that PPG and ECG signal was detected from sensor monitoring part, the data fusion network calculated the precision and accuracy level of sensor attribute and estimate the context level according to the sensor preliminary. After sensing description is analyzed, signal processing part delivers the secondary context including description of features. If the features are obtained from the physiological signal analysis step, data fusion network announce the level of sensor data as low level. If the features are generated from the integration level, the data fusion network represents the higher level of context. Ground based information indicates the predefined level of context and other indicators show the patterns or history about context level.

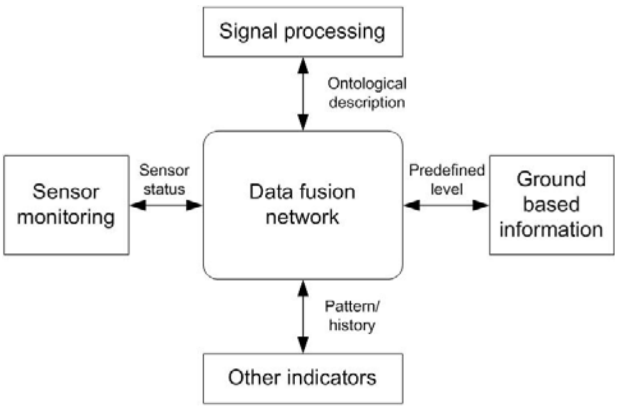


Fig. 2 Context alignment design

3.2 Level of Physiological context

3.2.1. Expert level physiological context

In-home wearable monitoring system basically requires low-cost, non-invasive wearable sensors without wiring camera or microphones, a data logging or communications module, and an integrated data analysis and management module. In order to build the natural health care application, we utilize a wrist type multi-physiological sensing system with PPG sensor, GSR sensor and SKT sensor that had been developed in previous work.

In case of layman data, family or non-expert people can easily read and interpret it in daily life. This context is intuitive to any user who wants to take the context because it integrates and fuses though decision fusion methodologies. Layman level context are latest processing version of sensed signal. On the other hands, expert level data is consists of integrated feature set which is analyzed by feature fusion methodologies. These are represented by parametric critics who are commonly used in clinical center.

Expert level physiological signal analysis follows general physiological signal analysis methodologies. We gathered three kinds of physiological signal from the different channel sequentially. Then each signal computed independently. In case of PPG signal, we are interested in the peak and its frequency domain characteristics. Thus, R-peak detection and spectrum analysis step is required additionally. In this step, we computed the heart beat, heart intensity and irregularity in PPG sensor, mean and transition in GSR and temperature sensor.

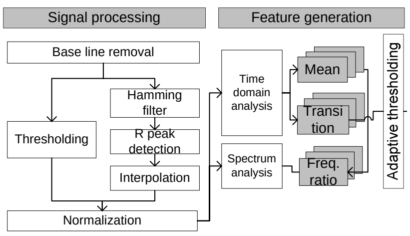


Fig. 3. Procedure of layman level physiological context generation

3.2.2. Layman level physiological context

Layman level physiological context indicates the abstract level context. Each context is under processed with temporal fusion methodologies. Entire body status is analyzed by the current status of sweat in skin surface, the temperature, heart status obtained from the wearable physiological sensors. After gathering each physiological status, each signal combines with the context integrator that indicates the relationship among three signals and additional wearer's general context such as male or female and activity, and innate characteristics. It also represents level of body condition under the four categories. If the wearer finds out some physiological changes, he/she can send the inner status monitoring information in which preliminary 5W1H context is filled with clinical measurement about each measurement to medical doctor or expert.

K-mean clustering method is applied to classify each pattern of three-dimensional body condition. The threshold values in decision maker are assigned based on the labeled classes and these values are adaptive threshold based on the user pattern.

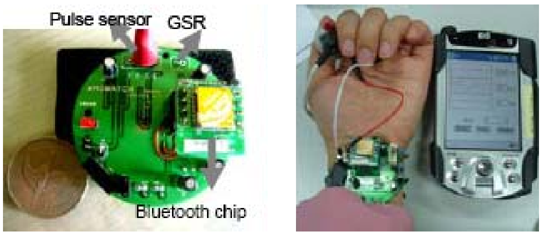
3.3. Information Disclosure service

User can disclose his/her physiological information to different *information requester* in the context-aware system, whose technical expertise and trustworthiness in the eyes of the user differ. We think under certain situations, competence of the information requester to interpret user's personal information and provide appropriate feedback is also important, along with his/her trustworthiness in the books of the user. Based upon trustworthiness and competence of the information requester, we calculate the benefit.

The requester who can provide the user "High" benefit is granted exposure to Expert level data while those who can provide "Low" benefit are given less-detailed layman data. A user (patient) is provisioned with a user interface on a wearable device (PDA) to specify trustworthiness and competence of information requesters. Information requestor is provided with an interface to request context information and acquire context info on his/her PC. Context information collected from the physiological sensors is transferred to the wearer's PDA. After receiving request from a requestor's PC, the identity of the requestor is verified and then the requestor is sent context information at the corresponding level of granularity. Context information can be transferred at two levels of detail i.e. expert level and layman level.

4. Implementation

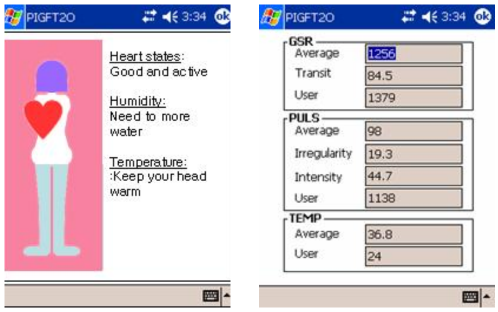
We expect that this system will enable patients to benefit from health monitoring systems without compromising the privacy of their medical records. This application can be extended to psychological analysis with appropriate application and robust internal status estimation methodologies. The sensor sends a detected signal at every 1 second. After the wearable physiological sensor acquires 3 kinds of signals, it transmits the acquired signals to PDA through Bluetooth.



(a) (b)

Fig. 4.Wrist type physiological sensor (a) hardware (b) sensing situation (c) analysis result

Fig. 5 and Fig. 6 illustrate the result of physiological context analysis according to the obfuscation level. In personal station, user can view the results of monitoring in body states as shown in Fig. 5. The layman level context is integrated three kinds of physiological signals. Fig. 6 is shown the results of classification in 3-dimensional feature space.



(a) (b)

Fig. 5 Physiological signal analysis results (a) layman level physiological context (b) expert level physiological context

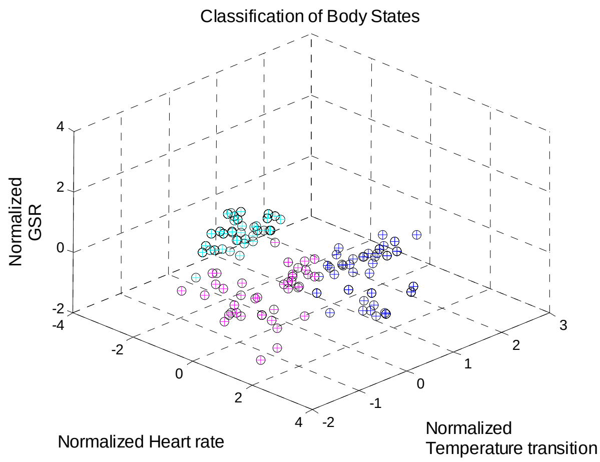


Fig. 6 Layman Level analysis results

A patient can use this interface to specify data access rules for data requestors, based on his/her preferences.

This server runs on the patient's PDA and processes context requests sent by different requestors to access the patient's context information. The requestor access rights are verified based on the privacy policy specified by the patient and then the context information is sent to the requestor accordingly.

The context information is transferred to the PDA of the patient (context owner) and is released to the PC of a requestor based on privacy policy which tends to disclose the information in proportion to maximize the potential benefit for the user. User can determine physiological information to be disclosed to different requesters at different levels of detail.

5. Conclusion and future works

We proposed the physiological context categorization and specification methodology by exploiting data fusion network for automatic context alignment. In addition we categorized the level of physiological context in terms of obfuscation. Low level of context is determined from the physiological signal sensing part and high level context is obtained from context integrator module. Context integrator combines with three kinds of features by exploiting the k-mean clustering method. As a prototype of our information disclosure mechanism, we developed an application which helps a user adjust the detail level of his/her physiological data disclosed to information requesters. In future works, we have a plan to make general context categorization module and to evaluate the physiological contexts. In addition, we will apply this information disclosure application for a long time monitoring situation.

Reference

[1] Michael Sung and Carl Marci, “Wearable feedback systems for rehabilitation”, Journal of neuroengineering and rehabilitation, 2005

[2] Holter NJ and Generelli JA, “Remote recording of physiologic data by radio”, Rocky Mountain Med Journal 1949:747-751

[3] Jason I. Hang and James A. Landay, “An Architecture for Privacy Sensitive Ubiquitous Computing”

[4] L. Marchesotti, S. Piva, C. Regazzoni, "Structured context-analysis techniques in biologically inspired ambient-intelligence systems," IEEE Trans. on SMC-Part A, vol.35, no. 1, pp.106-120, Jan. 2005.

[5] Salber, D., Dey, A.K., Abowd, G.D. The Context Toolkit: Aiding the Development of Context-Enabled Applications. In: Proceedings of CHI’99. 1999. pp 434-441

[6] J.I.Hong and J.A.Landay, “ an architecture for privacy sensitive ubiquitous computing,” in proceedings fo the 2nd conference on mobile systems application and services, pp 177-189, ACM Press

[7] S.lederer, C.Beckmann, A.Dey, and J.Mankoff, “Managing personal information disclosure in ubiquitous computing environments,” technical report IRB-TR 03-015, Intel research Berkley, 2003

[8] H.Chen, T.Finin, and A.Joshi, “A pervasive computing ontology for user privacy protection in the context broker architecture,” in Technical report TR-CS-04-08, Baltimore County, Maryland , USA, 2004

[9] V.Akman and M.Surav. “Steps toward formalizing context,” AI magazine, 17(3), pp55-72, 1996