Research Article

Visual Scheme Monitoring of Sensors for Fault Tolerance on Wireless Body Area Networks with Cloud Service Infrastructure

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1. Introduction

Much attention has been paid to wireless body area networks (WBANs) by a large number of scientists and many studies have been performed in this area as technology has increased. WBANs refer to local area networks of miniaturized embedded systems inside or outside the human body. Currently, this area is receiving much attention and activity from scientists [1]. To collect data about the human body in the past, there were only two methods. The first involved connecting an individual to equipment that is operated in a wired manner. The second involved dispatching a person to check the data at the place where the equipment is present. Due to the development of wireless communication technologies, it is possible to collect not only sensing data in a target area environment but also the human body data [1–6].

Early sensors were relatively heavy and large. However, the weight and size have been reduced gradually. Furthermore, a sensor should not impair normal activities. Thus, it should be possible to utilize a tiny sensor inside the human body that does not require battery replacement or attach a sensor externally to the human body without leading to inconvenience for individuals wearing hats, belts, or shoes. Due to the characteristics of the WBAN, if it is concentrated on a single person, a failure of equipment or abnormal data can be detected easily. However, it cannot take care of various types of large numbers of individuals simultaneously [2]. Previously studied areas of WBANs have focused on communication technology for implant devices and wearable devices and have involved portability outside, low power consumption, authentication methods, and nanotechnology [7–13].

In contrast, this paper proposes the visual monitoring system for fault tolerance (VMSFT), which complements the shortcoming of the WBAN and monitors all individuals that exist in the WBAN. Additionally, the VMSFT analyzes data collected from the WBAN. Through this analysis, the patients’ conditions and abnormal sensor operation or failure can
be detected. Importantly, this enables a proactive response. Also, VMSFT should be operated based on cloud computing service as IaaS (infrastructure as a service) [14, 15] and a VMSFT is a local monitoring system for humans within target area.

Figure 1 shows a schematic view of the overall concept of the VMSFT within cloud service infrastructure. Whenever abnormal data are generated, the VMSFT detects this anomaly and contacts an adjacent care center or emergency room for an immediate response.

2. Related Works

This section discusses existing related studies, primarily case studies and applied services, by using the WBAN. Previous studies on the WBAN [7–13] were completed with regard to minimum communication distance for sensors in the WBAN, minimum battery power consumption, and extremely tiny embedded systems for human body insertion. Sensors’ communication reach distance, transmission speed, and stability have been the commonly studied issues in communication technologies. However, once these systems have been introduced, a study regarding the formal framework of information regarding how to construct an anomaly detection in detail to enabled detailed monitoring.

3. Hierarchical Local Monitoring System Scheme with Cloud Service

As shown in Figure 2, the operation of VMSFT scheme has hierarchical structure for management of local monitoring system on cloud computing environment. The scheme divides it into two hierarchical management systems according to VMSFT management. The management scheme is, as stated, divided into two hierarchies: Layer 2 for managing physically divided metadata owned by individual and Layer 1 which contains virtual organization. Figure 2 shows architecture of the scheme of VMSFT within cloud computing service and control flow.

4. Anomaly Detection

The anomaly detection of the VMSFT is divided into two main categories, which are summarized below. The first is due to failure or malfunction of a sensor. The second concerns an abnormality in the data detected from the human body. The WBAN is a topology centered on human bodies, and it is highly sensitive to data because it has to be accurate and rapid.

4.1. Anomaly Detection due to Failure and Malfunction of a Sensor

To distinguish anomaly detection due to a failure and malfunction of a sensor, data are checked. Depending on the result of the data check, a response is determined.

(i) First, a data check is performed as follows.

(1) The receiving rates of the previous data are examined to calculate the average value.
(2) The receiving rate refers to the time taken to receive data after the first datum was received.
(3) If the average value exceeds twice the value calculated through the accumulated time, it is added to the Watch List Table. The Watch List Table consists of ID and error code only. (It is set up with a small data size by using an error code because monitoring is actually accomplished with a large number of human bodies.)

(ii) Three response modes are provided with respect to the checked data: as a basic setup, the level of the sensor is set to “High” if it is close to the heart or head while it is set to “Low” for the hands, arms, and legs. The rest is set to “Middle.”

(1) The response mode is determined depending on a level of sensor importance for the IDs added to the Watch List Table. (Basically, a level is classified into three (High, Middle, and Low), and a user can set up other levels via additions.)
(2) If a high-level incident occurs, this occurrence is sent to an adjacent care center or emergency room immediately as well as to the manager at the same time.
(3) If a middle-level incident occurs, this occurrence is sent to the manager immediately. If the reply time exceeds the standard time set, the adjacent care center or emergency room is notified.
Figure 1: Overall concept of VMSFT with cloud service infrastructure.

Figure 2: Scheme for VMSFT within cloud service infrastructure.
4.2. Anomaly Detection That Occurs due to the Human Body.

Anomaly detection that reflects a problem with the human body can influence life dramatically. Thus, a detailed setup is required for each user. Since the characteristics of each human body and disease name are different from one another, the response shall be different as well.

First, for a detailed setup, a user and his/her doctor should consult sufficiently with each other to complete the process. Generally, it is preferable for setup to be completed by a user's general practitioner.

This paper presents common definitions of anomaly detection for basic and detailed setups. More explanation of anomaly detection follows.

(i) Measured human body data change abruptly.

When measured data show abrupt, significant changes, a location, name of disease, and a reference level of the current status of a user are sent to an adjacent care center or emergency room unconditionally.

(ii) The human body data approach the reference value gradually.

The GP is informed about this change, while data of periodic change are sent so that a proactive response can be complete.

(iii) The reference values of the human body data can be set up by a user for each data section. Accordingly, each user can set up their settings differently.

5. Design of VMSFT

The visual monitoring system for fault tolerance (VMSFT) proposed in this paper can be divided functionally into human controller (HC), human manager (HM), coordinate converter, and viewer. A HC plays a role in sending the human body data measured in the WBAN to the HM. The HM analyzes data received from the HC and determines failure or anomaly detection through the analyzed data. A coordinate converter plays a role in processing data so that a user can monitor data through a viewer of the status by the HM. Finally, monitoring is provided via a viewer. The system architecture of VMSFT for WBAN should be shown in Figure 3.

The HC is formed in each human body in the WBAN. The HC consists of human information and detailed message analysis (MA). Human information consists of electroencephalography (EEG), electromyography (EMG), and electrocardiography (ECG) on data collected from human bodies, as well as GPS, location information data, and an ID that can identify each human body. The MA plays a role in sending data to the HM via an interaction broker, as well as analyzing the messages received from the HM.

The HM consists of user interface, resources monitor, and user link system notification (ULS notification). The user interface consists of the human information, which contains basic information (e.g., name of a human body, address, contact details, and name of disease) and range...
control for sensing data selection and communication setup. The resource monitor checks the human data received via the interaction broker. The resource monitor checks whether the received ID can be found in the human table, a list of human bodies inputted by users. If the received ID can be found, then the human data are analyzed by performing the fault tolerance notification (FTN) and anomaly detection. FTN and anomaly detection determine failure or abnormal state by inspecting the data transmitted from the installed measurement instruments or other sensors. The result of the determination on the data is transmitted as a ULS notification. A ULS notification is produced based on the result and sent to the registered adjacent care center or emergency room, according to the response level. This enables proactive responses. Furthermore, an importance level other than the basic three importance levels can be added by a user so that a more customized response is possible. The coordinate converter plays a role in processing the data to be customized in the viewer so that a manager can monitor the states running in the HM. The viewer provides the overall human states for monitoring using the data transmitted via the coordinate converter.

6. Implementation of VMSFT

The initial screen of the VMSFT is shown in Figure 4. ① in Figure 4 is a view that provides a user with the monitoring of all the humans. ② of Figure 4 is a view that displays the BAN visually if a particular human is selected in ①. Through ③, addition, editing, and deletion of ID, name, and age of the selected human, as well as other humans, can be completed. This view is configured such that it can receive inputs of the reference values of the sensors and human information, providing a view on EEG, EMG, and ECG.

Figure 5 is a view where basic information about a human can be entered if a user selects the Add button in ② of Figure 4. As a basic configuration element, name, age, address, phone, and disease are recorded.

Figure 6 shows a screen connected with the WBAN. As shown in Figure 6, the left side view shows a male with a green icon and a female with a pink icon, according to human sex. When one of the icons in the left view is selected, the right view shows the number as well as the front and back views of the selected human with the connected sensors. Moreover, the figure shows the number of correctly working sensors and the number of sensors with anomalies. The yellow circles indicate correctly working sensors, while the red circles mean that an anomaly has been detected. The green rectangular plays a role in sending the data collected from the sensors to the VMSFT via the WLAN. In the lower human information view, name and age are viewable, and other human bodies can be viewed via the combo box of the human number.

Figures 7 and 8 show an activated view by selecting EEG VIEW in Figure 6. Each table shows the EEG data collected from the sensors.
Figure 7: EEG in the VMSFT.

Figure 8: EEG in the VMSFT.

Figure 9: EMG in the VMSFT.

Figure 9 shows an activated view when EMG VIEW is selected in Figure 6. Each table shows the sensor data collected via the WBAN.

Figure 10 shows an activated view when ECG VIEW is selected in Figure 6. Data in the table represents measured data per minute and Figure 10 shows an example view of data measured every minute for a total of five minutes.

7. Conclusion

The WBAN sends human body data via the WLAN. The WBAN can affect human life directly, as it reflects data from the human body. Most of the previous studies in this area have concentrated on communication technology of implant devices and wearable devices, which can be used portably and conveniently, authentication methods, and low power consumption. However, few studies have addressed anomaly detection in human bodies and installed sensors via the collected data.

In this paper, the VMSFT was proposed to provide a proactive response by determining the presence of anomalies using the data collected through the WBAN. The VMSFT presented two criteria for anomaly detection to provide sensor fault tolerance and care for all humans in the WBAN. Also, VMSFT operated based on cloud computing service as IaaS and a VMSFT is a local monitoring system for humans within target area. We suggested the hierarchical scheme for management of VMSFT within cloud service infrastructure. In the future, a middleware system will be studied to expand the functions of the VMSFT outside of EEG, ECG, and EMG. To this end, we will define the functions by making use of XML, which is more convenient for this purpose, rather than using a database.
Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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