Sustainable Sensor Network Architecture for Monitoring Human Activities

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ABSTRACT

In this paper, focusing on a sensor network for monitoring human activities, the suitable architecture is discussed to obtain sustainability. After briefly showing a general architecture in present, the problems happening with long time usage are described. Then, our ideas are suggested to solve these problems.

CCS CONCEPTS

• **Information systems → Sensor networks**; *Mobile information processing systems*;

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1 INTRODUCTION

Monitoring human activities in working environment expects various useful applications, such as detailed analysis, efficient training, and planning effective workflow of their works. For achieving such systems, many environmental and wearable sensors are deployed for constructing a sensor network, and sensor data obtained from these sensors are exploited with their combination.

In many cases, the network are constructed with the structure designed for a certain application at the time of deploying the sensor network. However, along the long time usage, the architecture requires to change because the development and/or desuetude of hardware, changes or the purpose of the application, and so on. For instance, a hardware system and communication standards are developed day by day, and the IC chip of old hardware can disappear from the market. Also, activities of monitoring target can be changed with the improvement of their workflow. Thus, for enduring a deployed sensor network, the architecture must have the tolerance of some hardware/software changes.

In this decade, we have developed a sensor network in a real hospital, aiming to develop a system that support care givers and patients using activity recognition techniques, and have suffered such a problem. From our experience, we are now designing a sustainable architecture in which each component can easily replace, and the system doesn't need to construct from scratch even when the application is changed. In this paper, the strategy for achieving such a sustainable sensor network is discussed, focusing on the changes of sensor devices and applications.

2 BASIC ARCHITECTURE OF SYSTEM

Figure 1 shows an architectural overview of a sensor network, which we developed in past, for monitoring nursing activity in a real environment[1].

On the wireless sensor network layer, ZigBee based location system is deployed in the environment for obtaining nurses' location. Multiple Bluetooth-based accelerometers are worn by a nurse to obtain their body movement. Wearable Main Unit, which is associated with each nurse, is also worn by a nurse while recording their voice. Data of the location system is gathered by a sink host thorough ZigBee network directly. Accelerometer data are once gathered by a Wearable Main Unit through Bluetooth communication, and are associated with the nurse ID. Then Wearable Main Unit sends the data to a server with voice data through WiFi network.

On the Sensor Network Middle Layer, each server provides the gathered data to context processing modules and database on the Context Management Layer. Activity recognition engine recognize the activities of nurses with activity recognition technique, and the results are conveyed to real-time data base system and nursing context management server. Then the applications on the Application exploit these data to provide some services to users.

The components from the sensors on the Wireless sensor network layer to activity recognition engine are generic and reusable for another application. Figure 2 shows simplified structure of these main components. This is from our practical example. However, this is also general structure of many systems using activity recognition techniques.

3 CHANGES IN SENSOR NETWORK

About the hardware used to be a sensor network, many embedded sensor platform is now developed, especially a processor with lower power consumption. Also, sensors, such as an image sensor and an accelerometer, is getting higher resolution and higher frequency.

In the development of these hardware components, changes of processor are not so significant, because the embedded system that obtains sensor data is separated from the data processing component on the server. On the other hand, replacement of sensor must

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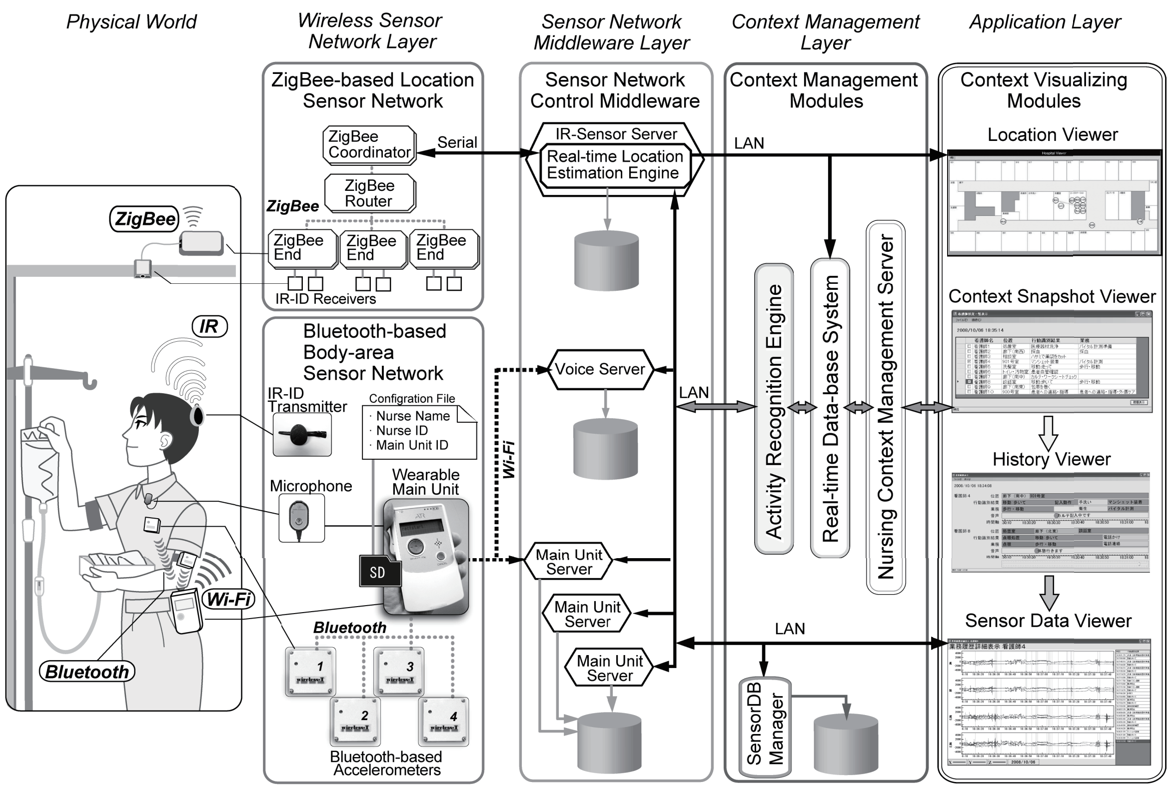

Figure 1: Architectural overview of a sensor network for monitoring nursing activity[1].

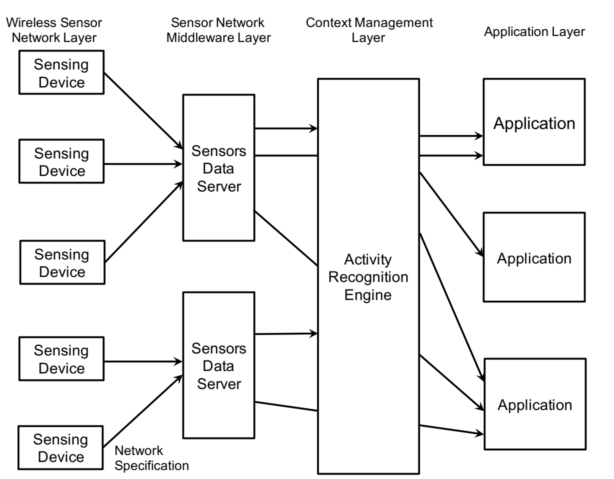

Figure 2: Simplifed structure of main components in a present sensor network system

be considered carefully. Here, considerable changes are sensor data format and sensor data type.

3.1 Sensor Data Format

Sensor data format can be changed by the replacement of sensors. For instance, when an accelerometer is replaced with the one which can get data more precisely, such as an accelerometer of ±3G range with 10-bit A/D converter and another of ±10G range with 12-bit A/D converter. In these cases, sensor data must be converted to the format on which the original system has been using.

This can be done both on the embedded sensor board and on a server which processes sensor data. From the view point of usage of a new application, the conversion should be done on a server. If it is done on the sensor board before sending to a server, more accurate data cannot be used by newer applications.

3.2 Sensor Data Type

When an existing sensor is replaced with a new type of sensor, original sensor data is required to be generated or simulated for executing existing components on upper layer correctly. For instance, an accelerometer is replaced with gyroscope, the accelerometer data needs to be produced for old applications. Since this has significant difficulty in some cases, the new type of sensor is demanded just for add instead of replace.

However, some types of sensors, such as location system, can provide similar result with other types of sensors. For instance, when a name based location system, which provides a name of the position, such as "Nursing station" and "Ward 305", is replaced with a coordinate based location system, which provides x, y coordinate based on a certain point origin of the floor, the coordinate can be converted to the room name easily.

In addition, as the same reason described in the previous section, the conversion is demanded to be done on the server.

3.3 Sampling Frequency of Sensor Data

In some cases, sampling frequency of sensor data can be changed. Sampling frequency is increased by a newer sensor and newer processor which run faster than original one in many cases, while sampling frequency may be decreased because of the trade-off with the resolution in a few cases. For both, resampling technique can be applied for arranging the sampling frequency for old applications. This resampling of sensor data can be done on the server as well.

3.4 Communication

In recent years, many novel communication standards have appeared, especially for IoT, such as Wi-SUN, NB-IoT, and LoRA as well as BLE. The difference of communication standards is generally managed by operating system, which provides same API, such as socket and serial, and programs doesn't need to consider it.

If the system requires to handle the difference of communication protocols by itself, especially on a server, the software module handling the communication protocol is required to be separated from the server program, and the server should be built as the one that can load communication handling module dynamically. In addition, the difference of processors' endian must be considered when sensor data are transferred in binary format, which is fundamental issue of computer networks. In this case, both a sensor device and a server must be deal with it in appropriate manner as programs on computer networks does.

3.5 Classification Algorithm

After receiving sensor data, the data is required to be inserted to pre-processing. Then the data are conveyed to the software modules to extract feature values and classification algorithm, both are represented as activity recognition module in Figure 2.

At first, the same pre-processing and extracting feature vector can work if the sensor data format is the same as the ones before sensor devices are replaced, which can be done by the methods mentioned above.

The changes of classification algorithms, such as replacing a current classification algorithm with the one that provides more accurate performance, is out of this scope. However, in general, classification algorithm can be easily replaced because the input and output of classification algorithms are same. Input for a classification algorithm is feature vector calculated by feature extraction, and output of the classification algorithm is a result of the classification. One considerable matter is that some classification algorithm using generative model provide the probability called "belief". If the new classification algorithm doesn't provide belief of classification result, it needs to be simulated with a certain method, similar to the one used for SVM in which fits a sigmoid function to the distance from classification border.

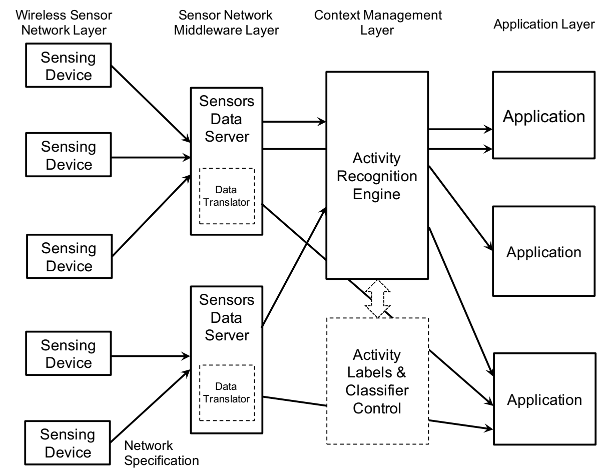

Figure 3: A sensor network architecture aiming to provide sustainability

3.6 Classification Target

The most teasing problem in a human activity monitoring system is the change of classification target. For instance, while original application uses just the classification result of "walking", "standing", newer application requires to more detailed classification result, such as "handling smartphone while walking" and "waving a hand while standing".

For the purpose, newer classifier working with newer classification labels must be created and inserted into the system. There are some studies to obtain newer labels while running an application in activity recognition[2], and new classifier can be inserted to activity recognition engine with these techniques. On the other hand, the original classifier needs to work with the new classifier, for providing the same result to an original application that doesn't need to get new classification label.

Moreover, activity recognition system is demanded to learn with obtaining data while its working time, in order to coping with the changes of users' activity, such as the one due to the changes of his/her habit, as well as to get higher classification accuracy. This is also studied very widely, focusing on online learning, semi-supervised learning, and active learning techniques.

4 SUSTAINABLE ARCHITECTURE

From these discussion, we are now developing a sensor network with an architecture shown in Figure 3. The components drawn with dashed line are new added components and functions to the architecture shown in Figure 2.

Data Translator in Sensor Data Server converts and translates the sensor data format, type and sampling frequency as described in section 3.1, 3.2 and 3.3. Activity Labels and Classifier control manages new data labels and create new classifiers as described in Section 3.5 and 3.6.

5 SUMMARY

In this paper, sustainable sensor network architecture for human activity monitoring is discussed, focusing on the replacement of sensor devices and insertion of new activity labels. Based on this discussion, we are currently developing a system that monitors a rehabilitation activities of elder patients in a real environment.

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