Design and Implementation of Middleware for GreenHouse Based on Ubiquitous Sensor Network

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Abstract. The USN middleware technology is used to filter lots of duplicate data collected from many sensor networks and convert the raw data into meaningful information for users to send it to applications, and provides services to make users could decide contextual information quickly and correctly through the data mining technique and analysis method. Even though it has been presently carried out the studies on such a USN middleware to apply it for various fields such as administration, medicine, science, transportation, and logistics etc., there are very few studies on the middleware suitable to agricultural environment which applications of IT technology have not been sufficient relatively comparing to other industries. In particular, for controlled agriculture, there are many difficulties on user's decision-making for efficient crop production due to a number of environmental factors affecting crop production. In order to solve such problems, this paper is trying to propose a USN middleware suitable to agricultural environment, which could collect greenhouse's environmental information and optimally manage crops through facility automation. The proposed middleware is composed of a sensor manager, context manager and control manager, which collects a variety of data from heterogeneous sensor networks, processes the collected data into information suitable to user's demand, and sends it to controllers of controlled agriculture, so that it could support users to be provided various application services and make decisions adequate to conditions.

Keywords: USN, MiddleWare.

1 Introduction

The recent trend in research and development on ubiquitous computing technologies is towards the direction to provide users optimum services suitable to conditions through context awareness, inference and cooperation based on data collected from various sensor nodes[1]. The USN technology is one of the ubiquitous computing's core technologies, which is applied to various fields including production, distribution, logistics, medicine, welfare, environment etc. to pursue enforcement of human life's convenience, improvement of quality of life, promotion of welfare, and

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T.-h. Kim et al. (Eds.): FGIT 2010, LNCS 6485, pp. 708–718, 2010.

security[2]. To build such the ubiquitous application services easily, a middleware is needed to connect the RFID/USN's hardware with the applications or the enterprise systems[2]. The middleware is a technology to filter lots of data collected from many heterogeneous RFID/sensor devices, process the event data, and then abstract it into meaningful information[3], and to send and process a great number of contexts and data arisen in the ubiquitous environment more efficiently[4]. Even though researches on the USN middleware are currently in progress for various fields, there are very few researches on the middleware focused on application services in agricultural environment that the application of IT technology is insufficient relatively comparing to other industries[5]. In particular, for the controlled agriculture, the production and the quality of crops is affected by the consistent management of various environmental factors such as temperature, humidity, insolation, CO2, ammonia, wind speed, rainfall etc. affecting crop's growth, and the precision control of environmental control devices including ventilator, windows, heater, lighting, image processor etc., so many difficulties are arisen in producer's decision making. This paper would like to propose an USN middleware suitable to agricultural environment, which could collect greenhouse's environmental information and manage crops optimally through facility automation in order to solve problems in such controlled agriculture environment. The proposed middleware is designed to collect and monitor the environmental information from sensors installed in the facility, and to provide the optimum service to the agricultural application service system by controlling the facility control devices through the corresponding context information processing when a problem is arisen, which helps user could be provided various application services and make a decision suitable to the situation. This paper is organized as follows. Chap. 2 explains the related researches, Chap. 3 analyzes requirements on the middleware to design the middleware based on the results, Chap. 4 implements the designed middleware, and finally Chap. 5 draws the conclusion of this paper.

2 Related Works

2.1 A design of Context Aware Middleware Based on Web Service in Ubiquitous Environment

Context-aware technologies for ubiquitous computing are necessary to study the representation of gathered context-information appropriately, the understanding of user's intention using context-information, and the offer of pertinent services for users. [6] this paper propose the WS-Cam(Web Services based Context-Aware Middleware) framework for context-aware computing. WS-CAM provides ample power of expression and inference mechanisms to various context-information using an ontology-based context model. this also consider that WS-CAM is the middleware-independent structure to adopt web services with characteristic of loosely coupling as a matter of communication of context-information. this paper describe a scenario for lecture services based on the ubiquitous computing to verify the utilization of WS-CAM. this paper also show an example of middleware-independent system expansion to display the merits of web-based services. WS-CAM for lecture services represented context-information itodomaits as OWL-based ontology model effectively, and

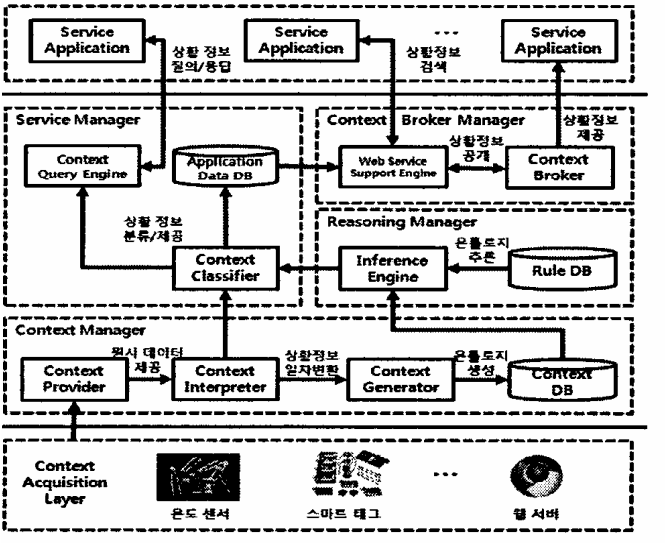

Fig. 1. The data flow diagram of Ws-CAM Framework

confirmed the information is inferred to high level context-information by user-defined rules. this paper also confirmed the context-information is transferred to application services middleware-independently using various web methods provided by web services[6].

2.2 Implementation of an Application System Using Middleware and Context Server for Handling Context-Awareness

Context-awareness is a technology to facilitate information acquisition and execution bysupporting interoperability between users and devices based on users' context. It is one of the most important technologies in ubiquitous computing. this paper propose a middleware and a context server for dealing with context-awareness in ubiquitous computing and implement an application system using them.[7]

The middleware proposed in this work plays an important role in recognizing a moving node with mobility by using a Bluetooth wireless communication technology as well as in executing an appropriate execution module according to the context acquired from a context server.[7]

In addition, the proposed context server functions as a manager that efficiently stores into a database server context information, such as user's current status, physical environment, and resources of a computing system. [7]

Finally, this application system implemented in this work one which provides a music playing service based on context information, and it verifies the usefulness of both the middleware and the context server developed in this work.[7]

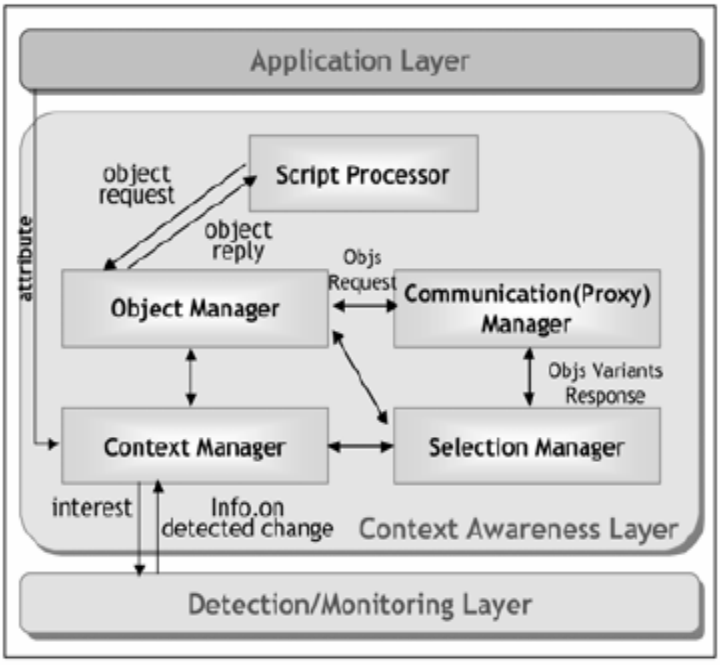

Fig. 2. Middleware Structure

3 MiddleWare

3.1 Middleware Requirement

To control and manage an agricultural facility efficiently, it should be considered the environmental aspect of system and the function of USN middleware. First, in the environmental aspect of system, when the difference of temperature between crops and the air is more than 4˚C in the facility, the condensation is taken place, so crops are damaged due to disease, and the production is significantly different depending on the light environment, temperature and humidity environment in the facility. In addition, since producers may suffer a loss due to unnecessary heating bills, in order to cope actively with it[8][9], it is installed the sensors for environmental information including temperature, illuminance, humidity, CO2 etc., and the control system such as heater, CO2 controller, wind speed/wind direction controller, ventilator etc. for the optimum environment. Second, the fundamental functions of middleware are the multiple query processing of collected services, management of sensing and meta information, creation of context information for sensing information, intelligent event processing required from the application layer[2]. Among them, sensors collect environmental variables (temperature, humidity, illuminance etc.) to provide adequate services for agricultural facilities, event processing is carried out to process data for pre-registered conditions if the certain condition is satisfied, and the collected environmental information is compared and analyzed with existing collected data. In

addition, a service is provided users to make adequate decisions by creating contextual information through prediction and inference.

The middleware is designed on the basis of such requirements.

3.2 Middleware Design

Fig. (3) shows the structure of USN middleware proposed in this paper for controlled agriculture automation, which is composed of a sensor manager (SM), context manager (CM), and control manager (CTM). The SM has a function to collect information taken place in the facility and to take charge of communication between middlewares, the CM has a function to analyze the raw data collected by the SM to convert it into actually usable information and to store and manage information. The CTM controls and manages the facility's device based on information analyzed by the CM.

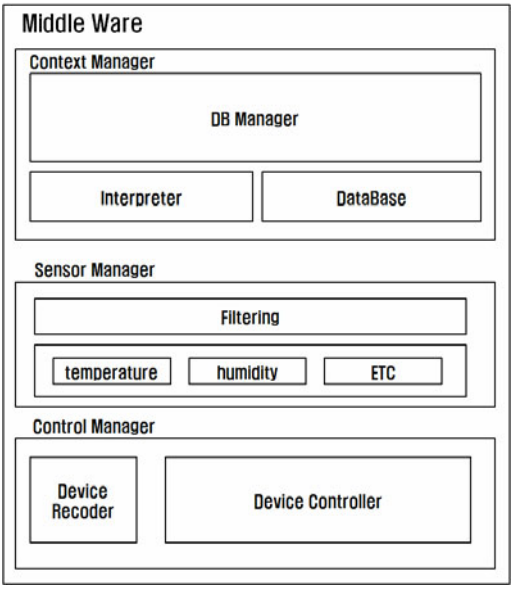

Fig. 3. USN Middleware Structure

3.2.1 Sensor Manager

The sensor manager is a module to deliver environmental information, which takes charge of interfaces between physical sensors and computers. The sensor manager carries out a function to collect information from the sensors including temperature, humidity, illuminance, CO2 etc. installed in the facility and the control devices such as ventilator, heater etc., sends constant clock signals to synchronize sensors in order to correctly transfer data between sensors and gateways without errors, and removes duplicate data by filtering to send it to the CM since the efficiency is decreased due to lots of data when receiving duplicate data.

3.2.2 Context Manager

The context manager could effectively manage the various contextual information to intelligently provide it to users. Such contextual information may be collected from the various sensors installed in the facility, and also collected via the Web such as information of the other facilities or the surrounding area[6]. The context manager takes charge of managing functions to acquire, process, represent, and store information for users and surrounding environment of users obtained from the various sources as above[6]. The context manager is composed of a context interpreter and a context DB manager as the Fig. (4).

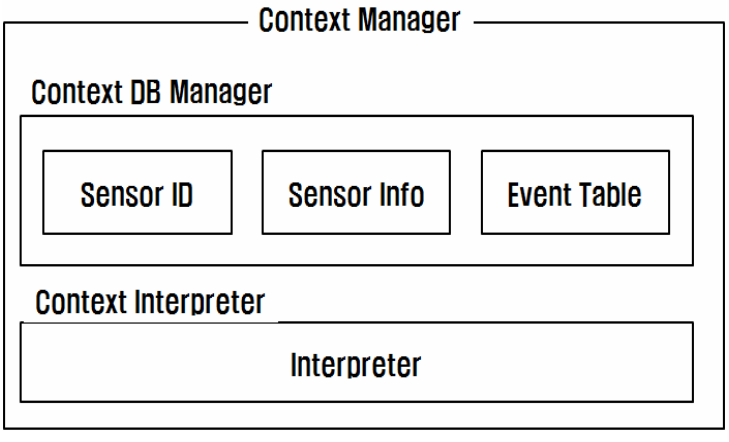

Fig. 4. Context Manager Structure

The context interpreter takes charge of converting the raw data collected from sensors into semantics that could be comprehended at the user level. Such converted information is stored in the database through the context DB manager. The context DB manager is comprised of Sensor ID, SensorInfo, and EventTable[10].

Table 1. Sensor ID

Sensor ID	Sensor function
1	Humidity
2	Co2
3	Fan
…	…

As the Table 1, Sensor ID table is comprised of sensor's ID and sensor's function attribute, and SensorInfo table allocates periods, time, measured values to be collected from sensors and assigns Group ID for each role of sensors.

Table 2. Sensor Info

Sensor ID	Location	Sample Cycle	Time	Value	Group ID
1	3-2 …	250	201009100423	40	3
2	4-1	250	201009100423	47	2
3	5-4	250	201009100423	30	1

The contextual information could be created through the data analysis module, which analyzes conditions of environment in the facility and crops based on such stored information, and the data mining technique, and the table is constructed as the Table 2 for intelligent event processing required by users. Certain problems occurring in the facility, i.e. many problems that temperature/humidity is too high to cultivate crops or the concentration of CO2 becomes so high that it has a bad influence on photosynthesis of crops, are predefined in the event table as the Table 3, and the facility is controlled if the problem is arisen. The interaction of CM is as follows.

Table 3. Event Table

Event	Group Id average Value
Turn on the Fan	40
Turn off the Fan	27
Turn on the light	30
…	…

The Group ID is given according to the sensor's function as the Table 2, the average value of sensor information values collected for each group is stored in the database as the form identical to the Table 4. The facility is automatically controlled if the event condition is satisfied on the basis of this value.

Table 4. Group ID

Group ID	Average Value
1	17
2	22
3	25
…	…

3.2.3 Control Manager

The control manager is composed of a device controller and a device recorder. The device controller requests the contextual information to control, and the device recorder records the current condition of control device to refer for the next service request.

Exploiting these two functions, the CTM uses the contextual information received by the CM to adequately control various control devices at the locations where the event is arisen, and sends the information to users in case of emergency. scenario for operating.

3.3 Scenario for Operating

Fig. 5 is the process of entire system. This SM periodically collects the environmental information such as temperature, humidity, CO2, wind direction, wind speed etc. from the sensor network installed in the agricultural facility. The collected information is stored in the database through filtering in order to remove duplicate data. The CM creates the contextual information from the stored information through the data mining and analysis, and uses the contextual information to send the control signal to the CTM through the predefined event manager. The CTM controls the controller in the corresponding area to efficiently operate based on the received control signal.

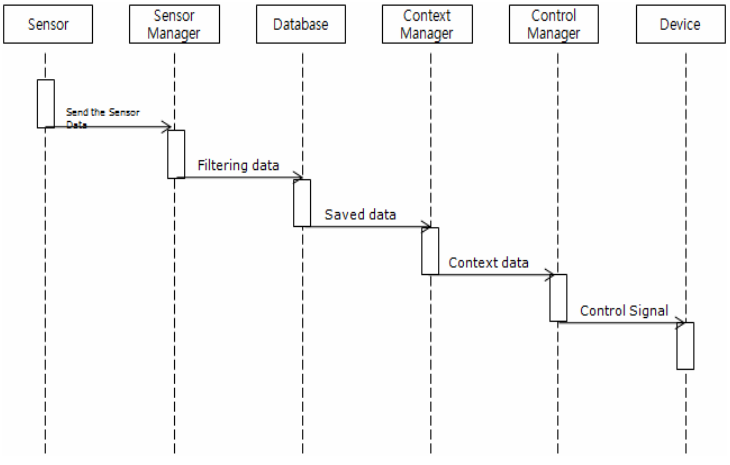

Fig. 5. Scenario Flowchart

4 Implementation

The proposed middleware is aimed at implementing the middleware for the Greenhouse suitable to the agricultural environment, and data collected through the sensor network is experimented for the event extraction according to the given conditions for the aim. In addition, it is constructed to confirm the results through the GUI implemented by the Microsoft Visual Studio 2005 C#.

Fig. 6 is the CM implemented with the C#, which is part of codes storing the environmental information received from the SM into the database, and Fig. 7 is the GUI to confirm the results of the proposed middleware. Through the GUI in the facility of Fig. 7 (Info), it could be confirmed the environmental information values such as temperature, humidity, illuminance, CO2, wind direction etc. collected from sensors, the intelligent event processing is confirmed through the event notification window as Fig. 8 opened when the contextual information exceeds the reference value, and the performance of middleware is confirmed by controlling various devices such as ventilator, heater etc in the facility through the Fig. 7 (Control).

```
namespace Context Manager
{
    class DB_Manager
    {
        private static string strCnn = @"Data Source='#DB.sdf';Encrypt = TRUE;";
        public static void insertEnvData(double[] pack)
        {

            String temp = Convert.ToString(pack[1]);
            String humi = Convert.ToString(pack[2]);
            String light = Convert.ToString(pack[3]);
            // String Ddate = Convert.ToString(DateTime.Now.ToLocalTime());



            string strSQL = "INSERT INTO Env(temp, humi, light ) VALUES(" + temp + ", " + humi + ", " + light + ")";

            SqlCeConnection cnn = new SqlCeConnection(strCnn);
            SqlCeCommand cmd = cnn.CreateCommand();

            cnn.Open();

            // cmd.CommandType = cmd.CommandType.Text;
            cmd.CommandText = strSQL;

            cmd.ExecuteNonQuery();
            cnn.Close();
```

Fig. 6. Part of Context Manager Code

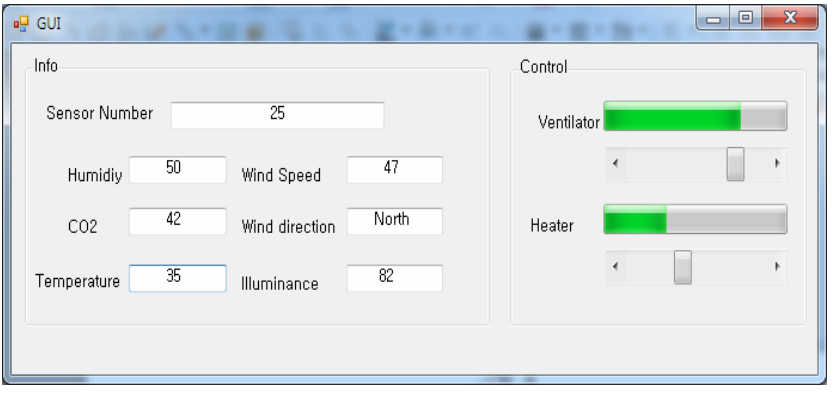

Fig. 7. GUI

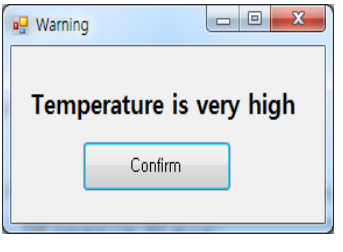

Fig. 8. Event Notification

5 Conclusion

This paper designs and implements the middleware to control the facility according to the contextual information collected from sensors for the agricultural facility automation suitable to the agricultural environment. The middleware is composed of the sensor manager, context manager, control manager, which the sensor manager sends various environmental information to the context manager, the context manager creates the contextual information and analyzes the agricultural environment based on the event, and the agricultural facility is controlled through the control manager, so it is minimized the problems that could be arisen in the facility. In addition, it is designed to monitor the information collected from sensors to support decision-making in the agriculture site. It is expected that the high profit would be given to the farm if the stability and reliability of facility is secured and the collected growth condition of crops is exploited through the middleware proposed in this paper.

Acknowledgements. This research was supported by the MKE(The Ministry of Knowledge Economy), Korea, under the ITRC(Information Technology Research Center) support program supervised by the NIPA(National IT Industry Promotion Agency) (NIPA-2010-(C1090-1021-0009)).

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