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Research paper

Context-Aware Service Recommendation System Using Sensor Data

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Abstract

Background/Objectives: With the advent of the Internet of things, context awareness technology has been widely investigated to recognize changes in the environment and to provide services accordingly.
Methods/Statistical analysis: However, providing an appropriate service to individual users is difficult because the system administrator determines the context awareness model. In addition, context awareness modeling based on ontology or collaborative filtering has a limitation in that it receives context-aware service only in a limited environment.
Findings: A context awareness system provides appropriate services through the process of identifying certain circumstances. To this end, it should obtain and analyze data of the circumstances around users, which are transferred from the sensor network or their smartphones. A sensor data analysis technology that can facilitate this function is essential to establish the accurate context awareness. As users can prefer different services under the same circumstances, a method of adjusting their service use patterns by examining their preferences based on the circumstances identified is also required. In this study, an integrated interface of context awareness services using sensors is established to satisfy the demand for accurately analyzing sensor data mentioned above and applying user preference to service user patterns. Moreover, a system that receives and reflects user feedback to obtain and analyze the service use patterns of users, consider individual preferences, and recommend appropriate services to users is designed and implemented.
Improvements/Applications: The service developer chooses sensors directly related to the service and determines whether to recommend the service according to the user's response, thereby providing the service that user needs

Keywords: *Context-aware, Recommendation system, Sensor data, Internet of things, Service*

1. Introduction

The Internet of things (IoT) is a technology that connects various objects equipped with sensors and communication functions via the Internet. In the upcoming IoT environment, people can use services provided from not only smartphones and computers but also various objects. With the advent of the IoT era, there is increasing demand for context awareness technology, which is applied to recognize changes in the circumstances or environments and provide appropriate services to these changes. The term "context" in context awareness has been defined differently by many researchers. The exist study [1] integrated the definitions of context proposed in other studies and defined it as information that can characterize everything related to interaction with users or applications such as people, location, and objects. In other words, context awareness means identifying and analyzing the current state of the aforementioned things and notifying users or apps of the analytical results[2]. In studies on context awareness, the stages are divided into a stage of individualization where users reflect their preferences directly through an interaction with the system, a stage of passive context awareness where the system identifies circumstances around users constantly and recommends services to them, and a stage of automatic context awareness where the system identifies circumstances around the user and constantly and automatically provides services to them[3]. Studies on context awareness have been conducted in various fields, including healthcare[4] and smart homes[5].

Recently, studies on providing services or contents to users through context awareness modeling are being carried out in various fields such as u-healthcare and smart home. Circumstances around users are identified using sensors or personal information, and appropriate services or contents are provided according to the circumstances. Accordingly, studies on modeling the user's circumstances based on the data obtained from sensors located around him or her have also been conducted. System complexity and size of circumstance information obtained are the most critical problems occurring in the process of implementing the context awareness system. To solve these problems, a mechanism for providing services through the recognition of surrounding environments has been designed to simplify the distribution of context awareness service. Moreover, a system that provides services to users according to the functions and basic setting by integrating the patterns of interaction between the system and user in the decision-making process was proposed[6].

The service-oriented context-aware middleware (SOCAM) architecture[7] was proposed to provide the context awareness mobile service for modeling various circumstances based on ontology. It was designed to distinguish and analyze various circumstances and consider portability in different context awareness systems. The context broker architecture-Ontology (COBRA-ONT)[8], which is represented in a Web ontology language called OWL, is a set of ontology used to describe the location, agents, incidents, and relevant characteristics in an intelligent conference room. This ontology was developed to support a pervasive computing system that promotes knowledge exchange, situation-based deduction, security, and context broker architecture (CoBrA). The context-aware middleware for ubiquitous robotic companion system (CAMUS) has been developed using the CoBrA technology for network-based robots[9]. The CAMUS provides a general data model for different types of context information obtained from external sensors in the user environments, apps, and users. It also provides a software framework used to obtain, analyze, and distribute context information.

A context awareness application program for healthcare cannot be adjusted according to the user's needs. Moreover, the user's behavior should be modified to apply a new technology. To solve this problem, a framework based on self-learning and probabilistic ontology was proposed[10]. This framework helps the context awareness application program accept the user's behavior in real time. The user's behavior patterns and tendencies are stored in the ontology, which is characterized according to the individuals using a probabilistic method. Thus, this framework provides an application program appropriate to the user's behavior pattern in a certain situation. A previous study[4] designed a u-healthcare service system individualized to implement the u-healthcare environment. In this study, a healthcare context information model based on ontology, which is used to infer individualized context information of users, was also proposed. Context information was extracted and identified by the context information model to be used for the implementation of healthcare service. The keynote system[11] performs individualized quality of service (QoS) estimation using the region-based hierarchical matrix factorization (HMF) method and recommends effective services regardless of location. This method integrates users and services into several user-service groups based on location and evaluates user satisfaction using the region-based QoS matrix generated using the model by applying the HMF method. The previous service objectifies each service to implement context awareness service according to individual needs and defines the performing conditions of objects as events to provide service in case of an event. As this service allows the user to directly define a relation between the event and service, the event and service are represented by a single construction. Furthermore, users who do not have professional knowledge of programming languages can use this service easily because a candidate selection method that sorts the list of available objects is applied in the process of service definition. In this service mash-up environment, users can generate context awareness services by recombining and connecting existing services. However, this process is still difficult for those who are not familiar with this field. To overcome this limitation, a system[12] that allows the user to easily generate new services in an environment with different sensors by establishing a user-oriented service environment and an ontology-based semantic sensor data processing method was developed. A context awareness model contains information related to various elements that exist in the environment of the user such as location, environment, and devices. It provides customized services to users by learning circumstances based on the information and naive Bayes classifier[13]. An individualized news article recommendation system[14] based on ontology shows news articles desired by the user. This system recommends relevant news articles by generating data of interests of a certain user in the long term and infers his or her current interests based on the data. The studies indicated above focus on the method of recommending contents by performing context awareness modeling using ontology or cooperative filtering and connecting and comparing sensor values with the context awareness model. However, the context awareness modeling method has a limitation in that a context awareness system manager, rather than service or content providers, generates a context awareness model irrelevant to the preference of a practical user or service provider. It leads to a decrease in the accuracy of context awareness. To solve this problem, a service recommendation system using sensor data is proposed in this study to consider the user's circumstances.

The structure of this paper is as follows. In Chapter 2, the structure of the newly proposed service recommendation system based on context awareness using sensor data is described. Chapter 3 shows the performance evaluation of the proposed system.. In Chapter 4, the conclusions of this study and the direction of future research are presented.

2. Materials and Methods

In this paper, a sensor data analysis technology based on density-based spatial clustering application with noise (DBSCAN)[15], which is a clustering algorithm, is applied to develop a system that can recommend services according to the circumstances around users or their preferences. This DBSCAN-based system recommends the most appropriate service to users using information on the location of users, present time, values obtained from sensors equipped in smartphones, and values obtained from sensors in apps to identify user preference and considering the services previously used by users in similar circumstances. As it is not assured that the recommended services are used in all circumstances, the uncommon service use of users should be excluded from the process of clustering algorithm application. Accordingly, data out of area with higher density than that in the data area are determined to be noise, and the DBSCAN algorithm is used to remove them.

The proposed system in this study mainly comprises the user's smartphone and context-aware service server (CASS). The CASS recommends services based on the user's sensor data and calibrates the recommendation accuracy by reflecting user feedback. The smartphone obtains various types of sensor data, transfers them to the CASS, and provides the recommended services according to the user responses.

The CASS mainly comprises the communication manager, user manager, context aware unit (CAU) manager, and context-aware engine (CAE), as shown in Figure 1.

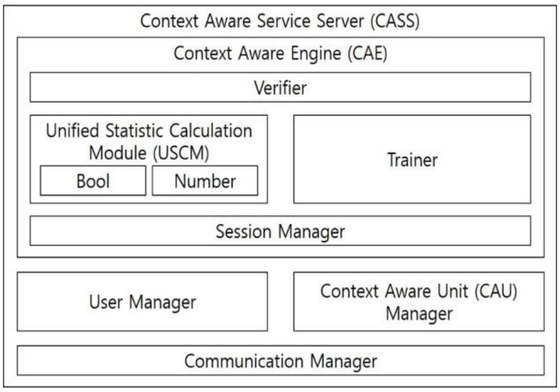

Figure 1:. Structure of the context aware service server

2.1. Communication Manager

The communication manager is a model used for HTTP-based communication between the user's smartphone and CASS. A new message type called signal has been newly defined for sensor data required in the entire service and requests sent to the smartphone and CASS. The signal comprises four fields—action, sender, receiver, and payload. Action is an indication of request sent from the message sender to the message receiver. Sender and receiver are token IDs of the sender and receiver, respectively. Payload is data required to perform action.

2.2. User Manager

The user manager compares a message sent from the context aware service (CAS), which is installed in the form of a home screen in the user's smartphone, with user information in the CASS to identify and distinguish users. In this process, a token is provided to each user for security.

2.3. Context Aware Unit Manager

The CAU is a library module that should be included in services using the CASS and is managed by the CAU Manager. The role of service and types of sensor data obtained can be identified based on the CAU of service installed on the user's smartphone. The CAU manager saves and accesses the CAU, sensor-related data, and an action that can be performed by the service in the database.

2.4. Context Aware Engine

The CAE uses sensor data from the CASS to recommend services to users. Sensor data are divided into Boolean data, which show only two types of values, and numeric data in the process of CAE to increase the recommendation accuracy. In addition, user feedback is obtained and reflected in the calculation of recommendation accuracy.

2.4.1. Unified Statistic Calculation

The unified statistic calculation module (USCM) calculates the recommendation score based on sensor data transferred from the user's smartphone. The calculation is performed using the Boolean data module or numeric data module according to the types of sensors. In the process of calculating a recommendation score after clustering, a higher score is given when the distance between the value of sensor data and the central point of cluster is shorter. However, a problem occurs when Boolean data are used because they have only two values, 0 or 1. Therefore, sensor types are classified in the calculation process. Thus, in the case of Boolean data, a recommendation score is calculated based on the frequency of the same value shown. In the case of numeric data, it is calculated based on clustering using the DBSCAN algorithm and distance between the value of sensor data and the central point of cluster. This process is performed in the entire service related to the sensor data obtained. The service that receives the highest recommendation score is recommended to the user. The recommendation score ranges from 0 to 1.

2.4.2. Session Manager

The session manager is required to maintain a connection during the process of gathering user feedback to confirm whether the user prefers the recommended service based on the recommendation score. The session manager maintains the connection by generating a temporary token, transferring the recommended service to the user's smartphone, and including the token in the user's feedback to be sent.

2.4.3. Trainer

The trainer is a module that receives user feedback and reflects it in the process of calculating the recommendation score. If the user wants to use the recommended service, it indicates that the recommendation result calculated using the USCM is correct. Therefore, the weight between the service and sensor increases to make the recommendation score higher. Thus, the trainer saves weight on sensors according to the services to reflect user feedback in the process of calculating the recommendation score.

2.4.4. Verifier

The verifier is a module that reflects user feedback in the calculation of recommendation score in the process of recommending a service to the user. If the user accepts the use of service, this module renews the user's service use pattern by including sensor data in the process of calculating the recommendation score.

3. Results and Discussion

To measure CAS's service recommendation accuracy, the same user runs the same application on a smartphone for a month to identify the user's pattern. Later, we used CASS to recommend applications and measure the number of times users use recommended services. Also, the direct execution of the service by the user is regarded as a factor that degrades the accuracy because CASS does not correctly grasp the service execution pattern of the user. Therefore, in order to evaluate the proposed context-awareness service recommendation system realistically, we measured the recommendation accuracy of context-awareness service measured by actual users. The service used in this process was based on Arduino as lighting service according to illuminance, and recommended score was calculated based on illumination sensor data and current time. Table 1 shows the accuracy of context-awareness service recommendation for lighting services measured based on 200 records using actual lighting services.

Table 1: Lighting service recommendation accuracy

Evaluation	Accuracy
Illuminance	90.5
Current Time	84.0
Illumination + Current Time	87.5

The accuracy of context awareness service according to illumination is 90.5%.However, 84% of the current time is not related to the lighting service compared to the illumination. When considering both illuminance and current time, it is 87.5%, which is lower than service recommendation accuracy considering only illuminance. In other words, recommending a low relevance factor may lower the service recommendation accuracy, so the service provider should determine the factor to be used as a service recommendation basis.

4. Conclusion

The most crucial purpose of context awareness in recent years is to accurately recognize circumstances around users and provide them with appropriate services depending on the analytical results. Accordingly, existing studies have focused on performing context awareness modeling based on cooperative filtering and ontology and comparing the values of sensors around users with the context awareness model to provide the most appropriate services and content to users. However, these studies have limitations in that services can be provided only in restricted areas such as hospitals and special facilities because the context awareness modeling manager, rather than service or content providers, directly generates a context awareness model. Moreover, the context awareness model generated is irrelevant to the preferences of practical users, service providers, or content providers, thereby reducing the accuracy of context awareness. To solve these problems, a service recommendation system based on context awareness using sensor data has been proposed. This system allows service providers to directly select necessary sensors for context awareness. It also reflects circumstances, which are identified based on the data of surrounding sensors, and user preferences to increase the accuracy of service recommendation through context awareness.

However, problems related to the amount of traffic generated in the user's smartphone and electricity consumption can occur in the process of obtaining sensor data through mobile communication. Thus, further research should be conducted to develop a method that provides services required by users while reducing the amount of resources used.

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