Situation and Social Awareness-based Personalized Recommendation Service in Pervasive Computing Environment

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Abstract— **Recently, many mobile techniques such as sensor networks or various types of mobile devices make it possible to provide smart services at any time, and anywhere. In despite of these remarkable advances of techniques, there are few personalized mobile recommendation services which fully consider user's current situation. Proposed recommendation algorithm efficiently defines user's current situation with situational data captured from various smartphone sensors. Also, the algorithm uses user's social network for efficiently filtering valuable items which are considered as authorities. To verify the usefulness of proposed technique, we implement a prototype of the personalized music recommendation service in which proposed recommendation technique is applied. Additionally, through the demonstration of implemented prototype, we investigate the effect of incorporating smartphone sensor data and social data to collaborative filtering algorithms.**

Keywords- Pervasive computing, situation awareness, socially awareness, collaborative filteirng, personalized recommendation

I. INTRODUCTION

The interests in mobile-based pervasive service are increasing with the advance of mobile technologies such as the sensor network and diverse types of mobile devices. In addition, the need for a new personalized pervasive system that is usable at anytime and anyplace is growing due to the emergence of the pervasively smart computing paradigm. Recently, personalized pervasive mobile application has been viewed as an efficient mean to improve human's life.

The impressive wireless and portable technologies we have today and emerging mobile computing paradigm offer a unique and real opportunity for us to create pervasive applications and environment specially designed to support the mobile human. Because of the advancement of the sensor technology, enormous amount of data generated from human's every life could be collected by various types of sensors. In addition, with the advance of sensor technology in the mobile devices such as smartphones, there is good chance to develop various kinds of pervasive mobile applications. Therefore, the emerging mobile computing paradigm offers a unique and real opportunity for us to create pervasive applications and to support the user who wants to be provided with cost-effective smart services such as a mobile healthcare service.

However, there are few mobile personalized services which fully consider a specific user's situation for providing appropriate recommendation service for each user's current physical condition and individual preference. Besides, many limitations of existing mobile pervasive applications results from a lack of correct and complete data of user's current state at the time of service, which can lead to wrong diagnoses and user's distrust for the service. Therefore, there is a need to develop newly approach for pervasively providing useful and authoritative recommendation services.

For this reasons, the aim of our work is to propose the technique for personalized mobile recommendation services which make it possible to provide useful and trusted personalized recommendation services at anytime and anyplace.

A. Contributions

In this paper, we propose a novel method for the personalized mobile recommendation services. Provided recommendation technique mainly consider user's current situation for providing usefully personalized and authoritative recommendation services. For developing personalized recommendation algorithm, we almost first try to apply social and situation awareness computing technologies in the mobile personalized service system. Our proposed recommendation algorithms not only consider user's current situation which is based on contexts captured from various sensors, but also user's social network data for efficiently filtering authorized items which are trusted by members of the social network. In addition, we mainly consider the mobile recommendation service through the smartphone and use sensors which are embedded in a smart phone. We show the usefulness of our proposed personalized recommendation algorithm through the implementation of the mobile music recommendation service prototype. In addition, we present possibility of the smartphone sensors in various personalized mobile recommendation services.

B. Organization

The rest of the paper is organized as follows. Section 2 describes background related with the proposed algorithms. Section 3 discusses in detail the algorithm for pervasively delivery useful and trustworthy personalized items. Section 4 presents the implementation of the application prototype.

Section 5 reports the comparative experimental evaluation between proposed recommendation algorithm and existing algorithm. Section 7 reviews related works. Finally, Section 8 concludes the paper and proposes the future work.

II. BACKGROUND: THE POSSIBLITY OF SMARTPHONE SENSORS

Context is what surrounds, and in mobile and pervasive computing the term is primarily used in reference to physical world that surrounds the user of a mobile device [1][2]. In our work, we use user's contexts in defining his/her current situation for the pervasive personalized mobile recommendation services.

TABLE I. THE KIND OF SMARTPHONE SENSORS

Smartphone sensors	Features
Ambient Light(ALS)	An ambient light sensor extends battery life and enables easy-to-view displays that are optimized to the environment.
Proximity Sensor	A proximity sensor detects how close the screen of the phone is to your body. This allows the phone to sense when you have brought the phone to your ear. At that point, the display turns off in order to save battery.
Global Positioning System(GPS)	A GPS takes signal from GPS satellites and use triangulation to calculate the user's exact location
Accelerometer	An accelerometer allows the devices of smartphones to detect the orientation of the device and adapts the item to suit the new orientation. The accelerometer in smart devices measures the acceleration of the device relative to free-fall.
Compass	A compass measures the strength of the magnetic field in three dimensions. The compass in the smartphone can be used to determine the angle by which the device is rotated relative to the Earth's magnetic north pole.
Gyros	A gyroscope is a device for measuring or maintaining orientation, based on the principles of angular momentum. Gyroscopic sensors used in navigation systems and gesture recognition systems in Smartphones and tablet PCs.
Back-illuminated Sensor	A back-illuminated sensor, also known as backside illumination (BSI or BI) sensor, is a type of digital image sensor that uses a novel arrangement of the imaging elements to increase the amount of light captured and thereby improves low-light performance.
Microphone Sensor	A microphone sensor converts sound into an electrical signal. A microphone in the smart phones can detect whether the user is near a sound source.

A trend that we may be seeing with mobile applications is that they work with various smartphone sensors. The tremendous growth of sensor technology in smartphones increases day by day. Table I shows kinds of sensors which are currently embedded in smartphones [3]-[5]. Aside from theses current smartphone sensors, smartphone sensors are more and more various because of remarkable advance of mobile device technology. Because the user always possesses the smartphone at anytime and anyplace, the definition of user's current situation with sensor data captured from smartphone sensors has a number of advantages. Therefore, we focus on useful possibilities of smartphone sensors in this work. And we mainly consider user's contexts captured from smartphone sensors to define the user's current situation.

III. SITUATION AND SOCIAL AWARENESS-BASED RECOMMENDATION ALGORITHM

In this chapter, we describe situation and social awareness recommendation algorithm in detail. Proposed recommendation algorithm considers three major concepts, situation awareness computing, and relational node importance in user's social network and collaborative filtering algorithm.

A. Situation similarity-based collaborative filtering

To recommend personalized mobile services with consideration for user's current situation, we use previous collaborative filtering (CF). CF is a technique generally used by many recommendation systems. CF is the process of filtering for information or patterns using techniques involving collaboration among multiple items or data sources [6]. Despite of the advantage of CF, it has been widely known that CF has many limitations. First, CF algorithm requests each user to directly assign the rating value to each item which is experienced by him or her, which causes inconvenience of users. Second, because CF methods make recommendation based on the users who are similar to the current user, user with different options and unusual preference cannot get good recommendations. Finally, general CF does not consider any user's situational data. A certain user's potential need for specific services may change with the situation which comes out dynamically in pervasive environment. For example, a female user *A* may prefer an Italian restaurant to a Chinese takeout restaurant on Christmas Eve.

In our work, we propose situation similarity-based collaborative filtering. Differ with previous CF in which the user similarity is used, situation similarity-based CF uses situation similarity to filter personalized recommendation services with the consideration for user's current situation. In addition, situation similarity-based CF pervasively computes the situation similarity between users without any needs to request each user to assign rating value to an item.

The situation similarity is used in our proposed CF algorithm to find users who were faced with the similar situation with the current situation of the active user. For pervasively computing the situation similarity between each user, user's history data is used. With user's history data, we could know what the situation a certain user is faced with when he or she experienced some item. To store this history data in advance, we consider the data model of user history like shown in Figure 1. We devise this model based on folksonomies. Folksonomy is one of the best core concepts of tagging system [7].

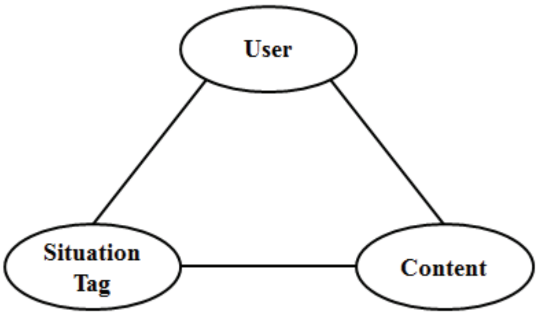

Figure 1. The data model of user context history

Instead of a tag in the model of a folksonomy, we consider a situation tag. The situation tag is automatically tageed with a certain item when the specific user experienced the item. To compute situation similarities between the current situation of the active user and the previously experienced situation of another user, we use situation-based tagging technique proposed in our previous work[8].

$$r_{ij} = \frac{\sum_k \left(S_{ik} - \overline{S_i}\right)\left(S_{jk} - \overline{S_j}\right)}{\sqrt{\sum_k \left(S_{ik} - \overline{S_i}\right)^2 \sum_k \left(S_{jk} - \overline{S_j}\right)^2}} \quad (1)$$

The first step for computing the situation similarity is to compose the user-situation matrix. Given S as the user-situation matrix, S_{jk} represents the situation importance of the user U_i with respect to the situation tag, ST_k. That is, ST_{jk} means the tagging frequency of the situation tag ST_k on the user U_i. $\overline{ST_i}$ represents the average of the total frequency of all situation tages which are tagged on the user U_i. In the second step based on the first step, we compute the situation similarities between users. The situation similarity, r_{ij} between the user i and j can be computed through the equation (1). We define the equation (1) based on *Perason correlation coefficient* [9]. Once other users hold high ranked situation similarity values are found, the prediction value for what items are proper with certatin user's current situation is computed by picking out items experienced by users who have high ranked similarity values with the current situation of an active user.

B. Social awareness-based recommendation ranking method

General recommendation systems recommend items which have high prediction value for a certain user only based on the similarity between user's preferences. For example, if the user *A* who was predicted as most similar with the certain user *B* experienced an invaluable item in the past, the item has high probability of being recommended to the user *B*. In conclusion, there has been much few consideration of recommending trustworthy items in common recommendation systems. In this work, we assume that trustworthy items in recommendation system could more satisfy the user who is faced with the certain situation than other items. In our work, we pay attention to the fact that many people have confidence in what neighbors experienced or knew about. So, we consider the social network to filter trustworthy items to recommend trustworthy items.

In social network analysis, the centrality of a node belonging to a social network determines relative influence of the node within the social network [10]-[13]. Lately node centrality as a measure of a node's influence by virtue of its central location has been widely used in various domains such as business marketing or advertisement. In the case of this work, we use the measure of the social node influence to rank items of the recommendation system.

For defining the social aware recommendation ranking mechanism, we consider a social graph $G_{PR}(V,E)$ which is extended from the model described in Figure 1. Components of the undirected graph G_{PR} can be described as a four tuple like $G_{PR} = \{U,C,T,E\}$ where U is a set of user nodes, C is a set of item nodes, T is a set of situational tag nodes, and E is a set of edges between each node. The relationship between components of G_{PR} is formulated as

$$E \subseteq \{<u,c,t>: u \in U, c \in C, t \in T\} \quad (2)$$

That is, the social model extended from the model described in Figure 2 can be viewed as a tripartite hyper-graph in which users, situational tags, and items are represented as each node. And edge is represented as hyper-edges connecting a user, a situational tag and item. In addition, the edge between user nodes is considered as social relationship. Based on this extended model, we compute the importance of each user node through equation (3).

$$IW(n_i) = \frac{\lambda}{C(N)} + d \sum_{n_j \in E(n_i)} \frac{IW(n_j)}{L(n_j)} \quad (3)$$

We define equation (3) based on PageRank. The well-known PageRank algorithm uses the hyper-link structure to determine web pages that contain authoritative information [14]. Equation (3) considers a directed link from a source to a destination as an endorsement of the destination by the source, but not vice-versa. For instance, numerous user nodes point to a certain user node, but very few user nodes receive pointers back from other user nodes. In other words, we identify reputed user nodes through equation (3), because user nodes with high indegree tend to be authorities [15]. In equation (3), d is a *damping factor*. $E(n_i)$ is the set of nodes which are adjacent to the node n_i. $L(n_j)$ is the number of all edges adjacent to n_j.

C. Combing situation similarity-based CF and social aware-based ranking method

To provide a specific user with mobile services which are authoritative and proper with the user's current situation, we try to combine the situation similarity-based CF and the social aware-based ranking method described in the previous section. Equation (4) computes specific rating for an item (*SRI*).

$$SRI(n_i) = \frac{1}{\alpha}\left[IW(n_i) + SS(n_i)\right] \ , \quad 2 \le \alpha \le 3 \tag{4}$$

$$SS(n_i) = \sum_{j \in E(n_i)} r_{ij} \tag{5}$$

SRI represents the rating value of the certain item which reflects suitability of user's current situation and authorities of the item. $SS(n_i)$ represents the suitability of user's current situation and can be computed by adding all situation similarity values calculated through equation (1).

In conclusion, the proposed situation and social awareness recommendation algorithm considers two novel approaches, situational awareness collaborative filtering and social awareness recommendation ranking method. Therefore, we could provide a specific user with services which are authoritative and suitable to user's current situation.

IV. PERSONALIZED MOBILE RECOMMENDATION SERVICE

For showing the usability of our proposed recommendation algorithm in pervasive computing environment, we develop a mobile application prototype which pervasively recommends personalized mobile music content to a certain users. Each type of prototypes is implemented with the situation and social awareness CF recommendation algorithm.

Figure 3 presents overall architecture of the personalized recommendation service prototype. The architecture of implemented prototypes consists of a *Recommendation Service Server* and a *Mobile Client* in which numerous sensors are embedded. *Mobile Client* sends situational data captured from considered sensors to *Recommendation Service Server*. Then, *Situation Similarity* (*SS*) engine in the server calculates situation similarity based on data which are stored in a situational history data repository. Next, the recommender module recommends items which are proper with a certain user's current situation through the wireless internet.

Table II describes the implementation environment with which all prototype systems are developed. Each prototype component communicates with each other through wireless internet. Also, we additionally use an electrocardiogram (EKG or ECG) sensor which is not embedded in the smartphone and communicates with user's smartphone through Bluetooth. EKG is commonly used to measure the rate and regularity of heartbeats, as well as the size and position of the chambers, the presence of any damage to the heart, and the effects of drugs or device use to regulate the heart such as pacemaker [16].

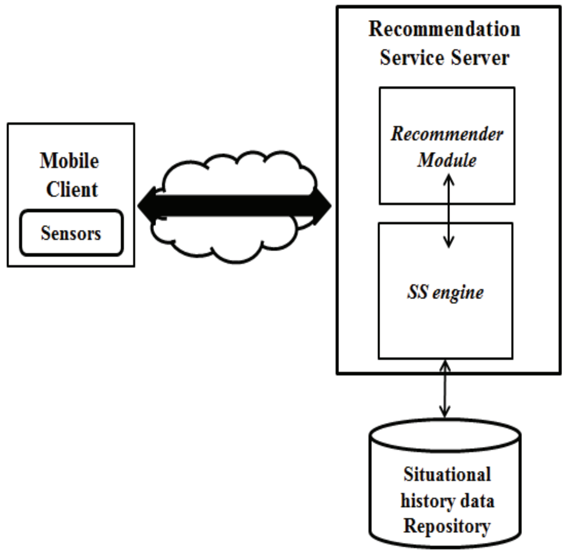

Figure 2. The architecture of the personalized mobile recommendation service

TABLE II. IMPLEMENTATION ENVIRONMENT

Prototype Component	Implementing Tools
Recommendation service server	- IIS Web server - .Net Framework, C# - Microsoft(MS) Access - Windows 7 Ultimate - Intel® Core™ Quad CPU at 2.4 GHz, and 4 GB RAM
Mobile client	- Java , JDK 6 - Android SDK 3.0 - Samsung Galaxy Play
Sensor module	- Java, JDK 6 - KDS-1046 (EKG) - Science Cube Lite (EKG Middleware)

For the demonstration of implemented recommendation system, we arbitrarily define the situation of the user 'Hannah' as [***Situation A*:** sex: female, age: thirties, EKG state: normal, season: summer, weather: raining, location: living room, time: morning].

Figure 3 and Figure 4 are showing the use of the implemented mobile service and the EKG result of the user 'Hannah' respectively. To use our implemented prototype, the user is needed to attach the sensor of EKG to his/her forearm like shown Figure 3. The QRS interval represents the time it takes for depolarization of the ventricles. If the QRS interval is regular like as Figure 4, it is assumed that user's current physical state is normal. Figure 5 is showing the provided music recommendation service with *Situation A*.

Figure 3. The use of implemented prototype

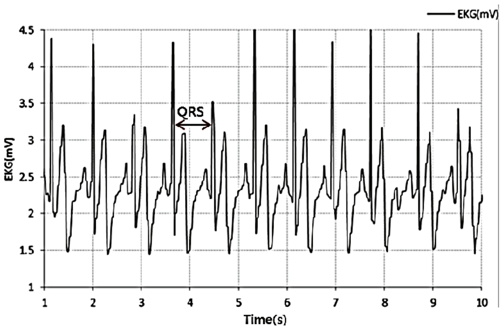

Figure 4. EKG diagram

Figure 5. The demonstration of the implemented prototype service

V. Related Work

In the following, three closely related approaches are surveyed and compared to our approach.

In [17], Shepisen et al. propose an information recommendation system based on hierarchical clustering of the tag space. The recommended information is identified using user profiles and social tag clusters to personalize the recommendation results. This study contributed to the attempt to utilize tagging technique to improve the recommendation performance. However, this work does not consider the improvement of CF-based systems with the help of situational tagging information to recommend more personalized services.

FLAME2008 is an approach for a Web-based information system intended for large user groups and large service set [18]. The objective of FLAME2008 is that users should be served according to their demands, which is perquisite for the acceptance of such services. User acceptance is crucial for the generation of revenue streams for service. The main idea of FLEME 2009 supporting this objective is an individual push of meaningful offers for information and services to the mobile devices based on situation and profile of each user. The situation is derived by information from different sensors and user profile information is additionally taken into account. But, this works had to request each user to input his/her information needs which is not considered as pervasive information service. Besides, the work does not consider any attempts to improve the authority of provided services. Therefore the work had limitations on pervasively recommending personalized mobile services.

In [19], Gay. V et al. develop the personal health monitor (PHM). PHM provides personalized, intelligent, non-intrusive, real time health monitoring using wireless sensors and a mobile phone. They develop an application and its algorithms. In this work, they consider various types of physical sensors. However, they do not consider any algorithms for pervasively providing personalized and authorized services.

VI. Conclusion And Futurework

The impressive wireless and portable technologies we have today and emerging mobile computing paradigm offer a unique and real opportunity for us to create pervasive applications and environment specially designed to support the mobile human. The emerging mobile computing paradigm offers a unique and real opportunity for us to create pervasive applications and to support the user who wants to be provided with cost-effective smart services such as a mobile healthcare service. However, there are few mobile personalized services which fully consider a specific user's situation for providing appropriate recommendation service for each user's current physical condition and individual preference. Besides, many limitations of existing mobile pervasive applications results from a lack of correct and complete data of user's current state at the time of service, which can lead to wrong diagnoses and user's distrust for the service. Therefore, there is a need to develop newly approach for pervasively providing useful and authoritative recommendation services.

In this paper, we proposed a novel method for the personalized mobile recommendation services. Provided recommendation technique mainly consider user's current situation for providing usefully personalized and authoritative recommendation services. For developing personalized recommendation services in pervasive computing environment, we almost first tried to apply social and situation awareness computing technologies in the mobile personalized service system. In addition, we mainly considered the mobile recommendation service through the smartphone and used sensors which are embedded in a smart phone. However, we do not take the experiment with the large dataset without any consideration about the scalability of our proposed recommendation method. Therefore, we will improve our algorithm by considering the factor of scalability in the next stage of our work.

ACKNOWLEDGMENT

This work was supported by the Gyonggi Regional Research Center (GRRC) and Contents Convergence Software (CCS) research center.

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