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A Context-aware Recommender System Architecture for Mobile Healthcare in a Grid Environment

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요 약

This paper describes a Grid-based context-aware doctor recommender system which recommends appropriate doctors for a patient or user at the right time in the right place. The core of the system is a recommendation mechanism that analyzes a user's demographic profile, user's current context information (i.e., location, time, and weather), and user's position so that doctor information can be ranked according to the match with the preferences of a user. The performance of our architecture is evaluated compare to centralized recommender system.

1. Abstract

In recent years, with their small size format and ubiquitous connectivity, mobile devices such as smart phones and PDAs can offer interesting opportunities for novel services and applications. In this paper, we propose a context-aware doctor recommender system called (CONDOR) to recommend appropriate doctors as well as hospitals for a patient or user at the right time in the right place based on his/her preference and, current context (location, time, weather, distance etc.) information. Existing centralized RS cannot resolve the contradiction between good recommendation quality and timely response which is essential in mobile healthcare. Centralized RSs are also prone to single point of failure. So we propose a new framework by integrating Grid technology with context-aware recommender system to alleviate these problems. The construction process of context-aware recommendation and the results of the experiments are also discussed.

2. Introduction

In recent years mobile computing, where users equipped with small and portable devices, such as mobile phones, PDA's or laptops are free to move while staying connected to service networks, has proved to be a true revolution [1]. Applications have begun to be developed for these devices to offer online services to people whenever and wherever they are. One of the most popular tools provided in e-commerce to accommodate user shopping needs with vendor offers is recommender systems [2].

However, it is becoming clear that the use of mobile technologies will become quite pervasive in our lives and that we need to support development of applications in different areas. In particular, we have recently been involved in the development of context-aware Recommender system in mobile healthcare setting. Any patient or user carrying mobile phone or PDA moves different places he/she has never been to before and may face difficulties to find good doctors or hospitals in those unknown places for emergency healthcare. Therefore, in this research, we propose a context-aware doctor recommender system (CONDOR-CONtext-

aware DDoctor Recommender), to recommend appropriate doctors as well as hospital for a patient or user at the right time in the right place. This time-critical recommendation requires establishing system architectures that allow support infrastructure for wireless connectivity, network security and parallel processing of multiple sources of information. Moreover, unlike stationary desktop oriented machines (PCs), mobile devices, (smart phones, PDA's) are constrained by their shape, size and weight. Due to their limited size, these devices tend to be extremely resource constrained in terms of their processing power, available memory, battery capacity and screen size among others [3].

Furthermore, most recommender systems of today's are centralized ones which are suitable for single websites but not for large-scale distributed applications of recommendation. Centralized recommender systems cannot resolve the contradiction between good recommendation quality and timely response. In case of performance, the centralized architectures prone to single point failure and cannot ensure low latency and high reliability which is essential in mobile healthcare [4].

In this paper, we propose a new architecture by combining context-aware recommender system with Grid technology for mobile healthcare service. And there are very few researches that integrate recommender system with Grid. Traditional recommendation mechanisms like collaborative and content-based approaches are not suitable in this environment. So we present a recommendation mechanism that analyzes a user's demographic profile, user's current context information (i.e., location, time, and weather) and user's position so that doctor information can be ranked according to the match with the preferences of a user. The performance of our architecture is evaluated compare to existing centralized recommendation systems is also shown

The paper is organized as follows: Section 3 briefly reviews related works. Section 4 describes proposed architecture requirements. Section 5 presents the proposed system architecture. Section 6 shows the evaluation of our architecture and finally section 7 concludes the paper.

3. Related Works

3.1 Decentralized Recommender System

Modern distributed technologies need be incorporated into recommender systems to realize distributed recommendation. Chuan-Feng Chiu, et al proposed the mechanism to achieve community recommendation based on the design of the generic agent framework which is designed based on the peer-to-peer (P2P) computing architecture [5]. Peng Han, et al proposed a distributed hash table (DHT) based technique to implement efficient user database management and retrieval in decentralized CF system [6]. Pouwelse et al. also proposed in [7], a P2P system capable of social content discovery called Tribler. Tribler uses an algorithm based on an epidemic protocol. However the above methods did not consider context-awareness which is very important in case of mobile computing. Also the privacy issues need to be considered in P2P systems. In real-time healthcare service, parallel processing of multiple sources of information is very important.

Today Grid computing promises the accessibility of vast computing and data resources across geographically dispersed areas. This capability is significantly enhanced by establishing support for mobile wireless devices to access and perform on-demand service delivery from the Grid [8]. Integration of recommender system with Grid can enable portable devices (mobile phones, PDA's) to perform complex reasoning and computation efficiently with various context information exploiting the capabilities of distributed resource integration (computing resources, distributed databases etc.). The author in [4] proposed a knowledge Grid based intelligent electronic commerce recommender systems called KGBIECRS. The recommendation task is defined as a knowledge based workflow and the knowledge grid is exploited as the platform for knowledge sharing and knowledge service. But the author did not explain well how efficient it will be in e-commerce sector. Also context-awareness for mobility support is not considered.

Our architecture considers context-awareness and recommends the appropriate healthcare service with the help of Grid which is a new platform for distributed recommender system.

3.2 Context-aware Recommender System

Context is any information that can be used to characterize the situation of an entity. An entity is any person, place or object that is considered relevant to the interaction between a user and an application, including the user and application themselves. Examples of contextual information are location, time, proximity, user's status and network capabilities. The key goal of context-aware systems is to provide a user with relevant information and/or services based on his current context [9].

There are many researches in the literature to use context-aware recommender system in different application areas like travel, movie, music, shopping etc. [10-12]. They use Bayesian network to represent user preference model. But constructing Bayesian network from data is very complex and time consuming when the dataset is too large. We propose a new application area which is very important for our life that is context-aware healthcare recommender system

using Grid technology. Also we use another efficient approach for recommendation.

4. Proposed System Architecture Requirements

To provide recommendation, the proposed CONDOR system needs to collect various kinds of information as described below:

- a) *User Demographic Information*: These include user's age, gender, education, income range, work experience etc.
- b) *User Context Data*: This includes user current location, time and weather information. The location information is collected by two major location positioning technologies, Global Positioning System (GPS) and Mobile Positioning System (MPS). The distance is the Euclidean distance between user location and doctor location. Time is provided by the computer system and the weather information is obtained from the weather bureau website.
- c) *User Preference Information*: This is the user's tendency toward selecting certain alternatives among others. A survey by US National Institute of Health [13] showed that board certification, rating (reputation), type of insurance accept, location (distance), visit fee, hours the service is available and existence of lab test facility, in descending order, are the most important factors to user/patient in choosing a new doctor. Therefore, in the proposed model, these are included in the user preferences and also consider as context parameters.
- d) *Doctor Information*: We assume that different doctors, hospitals and healthcare services register with our system. Also we will encourage them to provide their information. So our system can access their database for collecting doctor information. Also from different website of hospitals we can collect information about doctors.

5. Proposed System Architecture

The overall CONDOR architecture is shown in figure 1. Our architecture consists of user interface, middleware and data Service. The major components of our architecture are described as follows:

- a) *Web portal*: This is used as the web interface for the user which can be accessed from users mobile's or PDA's internet browser. Users'/patients', doctors, hospitals and healthcare services register their profile or information through this web portal. So the system can get his demographic data (age, income, education etc.). Also user submits his recommendation request through this portal.
- b) *Context Manager*: The context manager retrieves information about the user's current context by contacting the appropriate context Information services (see the fig 1) and send context information to recommendation web service.
- c) *OGSA-DAI*: OGSA-DAI (Open Grid Service Architecture-Data Access and Integration) [11] is an extensible framework for data access and integration. It exposes heterogeneous data resources to be accessed via stateful web services. No additional code is required to connect to a data base or for querying data. OGSA-DAI supports an interface integrating various databases such as XML databases and relational databases. It provides three basic activities- querying data,

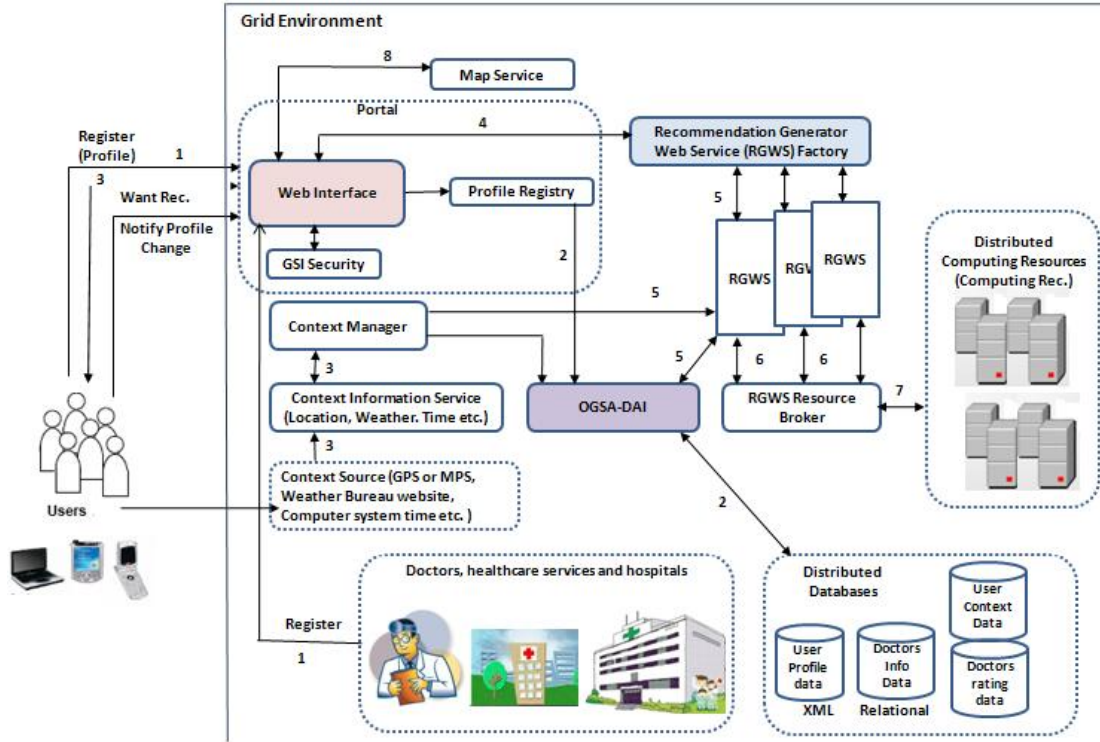


Figure 1: Grid-based Context-aware Recommender system architecture for mobile healthcare

transforming data, and delivering the results using ftp, e-mail. All information regarding users, doctors, hospitals etc. are saved through OGSA-DAI to the distributed databases.

d) Recommendation Generation Web Service (RGWS)

This actually generates the recommendation using some recommendation technique. As traditional recommendation technique like collaborative and content-based approaches cannot be used in this situation, we developed a efficient recommendation technique.

The workflow of our architecture is as follows:

- (1) First, user/patient, doctors, hospitals and healthcare service register with the system. These information are saved to the distributed databases through OGSA-DAI.
- (2) When a user or patient needs the recommendation service, a request is sent, with the user's current position and type of doctor the patient requires, to the system through web portal or interface.
- (3) Then recommendation web service is invoked from the web service factory for that user. It then collects necessary information (user profile data, current doctor's information on that location) through OGSA-DAI from different distributed databases.
- (4) Then the service broker schedules the recommendation service to run on different machines and a list of recommended doctor's along with hospitals name, location, distance etc. are passed to the user through the web browser.
- (5) When the user selects a doctor, his location map is displayed through the map service on the mobile phone display.

5.1 Recommendation Generation Process

Let consider a simple context space with three contexts (C_1 = Board Certification, C_2 = visit fee, C_3 = rating) and two doctors to be ranked (D_1 and D_2) in user current situation, d_1 and d_2

denotes the distances of the doctors position from user current location. First, we need to find out which doctors are most appropriate or similar to user. Suppose D_k denotes doctor k , C_n denotes context parameters n of D_k and w_n denotes relative weight of C_n . Let $w_n(Dv_{k,n})$ be the weighted ranking value of D_k with respect to C_n ($0 \leq w_n(Dv_{k,n}) \leq 1$). The method of calculating $w_n(Dv_{k,n})$ is shown in table 1. So the similarity of D_k for a user u will be calculated as follows:

$$Sim(u, D_k) = \sum_{i=1}^n w_n(Dv_{k,n}) \quad (1)$$

Higher the similarity means high possibility to choose that doctor for a user. But distance is also a matter. Usually user is more likely to choose a doctor with highest weighted ranking value and minimum distance. In case of emergency, distance will get more priority and user will choose a doctor with minimum distance and moderate similarity. So we consider a distance weight variable (DWV) for measuring the user's sensitivity to distance. DWV for a user u with respect to different doctors D_k from the similar doctor list is calculated as follows:

$$DWV(u, D_k) = \frac{\log_2 \left[\frac{\text{distance}_{\max}(u, D)}{\text{distance}(u, D_k) + 1} \right]}{\log_2 \text{distance}_{\max}(u, D)} \dots \dots \dots (2)$$

where, $k = 1, 2, 3, \dots, n$ (No. of doctors)
 $\text{distance}_{\max}(u, D)$ = The maximum or farthest distance of

a doctor location from user current location among the similar doctors.

distance (u, D_k) = The distance between the user and any doctor.

In the formula (2), DWV will be reduced when distance (u, D_k) increases and DWV is also normalized. I.e., if distance (u, D_k) = distance_{max} (u, D), then DWV = 0, if distance (u, D_k) = 0, then DWV = 1.

Therefore, the final score for any doctor D_k for a user u in user's present position with current user context is calculated as follows:

$$\text{Final Score}(u, D_k) = \text{Sim}(u, D_k) + \text{DWV}(u, D_k)$$

Based on the final highest score, the doctors will be ranked and recommended to that particular user/patient

Table 1: $w_n(Dv_{k,n})$ Calculation Method

Rank value $Dv_{k,n}$ for D_k w.r.t. $C_{n=\text{has_board_certification}}$
User Requirement: desired: "true" If actual = "true" then $w_n(Dv_{k,n}) = 1.0$ else $w_n(Dv_{k,n}) = 0.0$ // not present
Rank value $Dv_{k,n}$ for D_k w.r.t. $C_{n=\text{visit_fee}}$
User Requirement: desired: "low" "average" If actual = "low" then $w_n(Dv_{k,n}) = 1.0$ // perfect fit else if actual = "average" then $w_n(Dv_{k,n}) = 0.5$ // else $w_n(Dv_{k,n}) = 0.0$ // high rate

6. Evaluation of our Architecture

We are concentrated on the on-line workload of our system. We considered a service station (centralized recommender system) in which users, each with a random characteristic value and a vector of terms arrive in accordance with a Poisson process with a rate b . Upon arrival, a user either enters the service if the recommendation engine is free at that moment or else joins the queue. After the engine has generated a recommendation list for a user, it then either serves the longest-waiting customer or, if there are no waiting customers, waits for the arrival of the next customer. In general, in the centralized recommender system the single server handles all the requests and the service waiting time and server load increases linearly when the no. of users increases. But in our distributed architecture which utilizes grid technology, the server load is not increased linearly as shown in figure 2. Here,

$$\text{Load } \rho = (\text{mean arrival rate}/\text{mean service time})$$

Thus our distributed context-aware recommender system's response time is higher than the tradition centralized RS which is essential in real-time healthcare service.

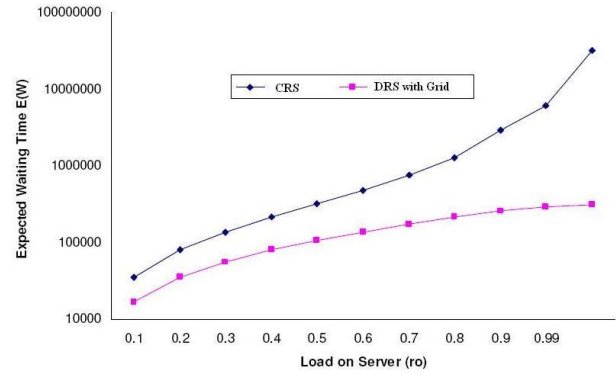


Figure 2: On-line workload comparison of our architecture with traditional centralized recommender system

7. Conclusion

In this paper, we propose a new framework of context-aware recommender system in healthcare application. We combine grid technology with recommender system which recommends appropriate doctors for the patient based on his current context parameters. Our evaluation shows that our architecture is efficient than the existing centralized ones.

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