A Framework for Personalized Healthcare Service Recommendation

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***Abstract*—Development of the Internet enables numerous healthcare services to be available to many service consumers. As a result, many brokering web sites such as healthcare service portals and search engines are deployed to support users' choice. However, to provide better healthcare to the novice users, systems need more sophisticated mechanism for healthcare recommendation. In this paper, we propose Healthcare Service Recommendation Framework (HSRF) that considers health status and various contexts of each user. HSRF arranges healthcare services based on medical similarities between user and services. We successfully implemented the framework and confirmed its functionality and feasibility.**

Keywords-component; healthcare service; recommendation

I. INTRODUCTION

The Internet, which brought the most innovative improvement on information society, has also brought many remarkable changes of healthcare services. Via the Internet, accessing information about healthcare services became relatively easier for service consumers who need adequate medical treatments. Moreover, consumers can communicate with doctors to get medical advices or to make appointment by e-mail or instant messengers, which are more convenient communication channels than by phone. Because of these benefits, much more healthcare service providers started publishing web sites for their service on the Internet competitively; as a consequence, consumers can obtain wide choice of services and better service quality.

However, there are also negative effects caused by exponential growth of the healthcare web sites. Because of too much information available, consumers cannot easily choose proper healthcare service among them. Some of them might not be able to judge what healthcare services are helpful because evaluating those services usually requires medical expertise. Moreover, there might be over-advertising web sites that show off exaggerated information about services. In this case, healthcare services on the Internet may confuse service consumers and make them more questionable.

To help users to choose a proper service among the available services on the Internet, many brokering web sites for healthcare services such as healthcare web portals and search engines have been developed [5][6][7][8]. The users can use the brokering web sites as starting points and find appropriate healthcare services using them. This improvement allows the users to access information about the services much easier than before, and the healthcare providers to save more lives. The brokering web sites, however, showed their limitation that more sophisticated mechanism is required in the domain of healthcare. The most of the users who does not have any knowledge about healthcare or any idea what is wrong with their bodies cannot find out proper healthcare services. What they need is not organized information about services, but a professional guideline to the most appropriate services for a specific user.

Therefore, recommendation systems for better healthcare are proposed. Recommendation system for the healthcare is a web site that recommends healthcare services or provides useful information to the users considering. Healthcare Provider Recommendation System [3] is an example of well proposed healthcare recommendation system. User can search the healthcare providers using location, providers' specialty, and reputation. However, what this system could not solve yet is that novice users and patients still may not be able to find out proper treatment for them when they do not know their exact health status. Because the most of people lack of medical knowledge, the system may not be effective in real life.

To recommend appropriate healthcare services to novice or nonprofessional users more effectively, recommendation system must be aware of not only users' essential contexts such as location, but users' health status. In this paper, we suggest the Healthcare Service Recommendation Framework (HSRF) that can recommend healthcare services to each service consumer considering their health status. A main functionality of HSRF is that the framework automatically selects suitable healthcare services for a specific user among enormous services in the service repository. As a result, healthcare service recommendation of the framework can be personalized and very helpful for novice users. Moreover, to enhance extensibility of the framework, HSRF supports a convenient registration for new healthcare services or recommendation logics. Furthermore, we implemented HSRF; we evaluated the framework's functionality and feasibility successfully.

In the next section, we analyze other research efforts for healthcare service recommendation. Then, our approach to personalized recommendation is minutely described in Section

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3. In Section 4 we describe implementation result and evaluation of the framework, and we concluded this paper at Section 5.

II. Related Work

Bachus et al. [3] have been holding a U.S. patent that is Healthcare Provider Recommendation System (HPRS). A consumer who experienced good of a healthcare service can register the service's provider on this system. Information about registered and accumulated services is provided to the other users; a user who is willing to be treated can query to the system using provider's contexts such as location, specialty, and reputation. This system can encourage information sharing between consumers, and rating healthcare services may be honest and actually helpful for consumers' point of view. However, information about the services may not be possible to show professionalism, because services are registered by laymen. Besides, the system cannot consider user's contexts, especially the health status, so novice users may not receive successful recommendation results.

ABC Homeopathy [4] is a healthcare web site that proposes remedies or medicines according to the users' symptoms. Using this web site, a user can choose multiple symptoms of each body part, and retrieve information about remedies for the selected symptoms. We can regard that this system considers health status to recommend remedies. However, results are too simple and limited to remedies only. Moreover, it does not handle enough health status that is required for fine recommendation, and still, it is not useful when users could not be aware of their specific symptoms.

III. Healthcare Service Recommendation Framework

A. *Framework Definition*

Healthcare Service Recommendation Framework (HSRF) is a computerized system that recommends suitable healthcare services to service consumers based on their various health status. In other words, the framework acts as a mediator for business or nonbusiness interactions between health service providers and consumers. Therefore, it is an essential functionality for medical web software such as e-health portals or search engines for healthcare services.

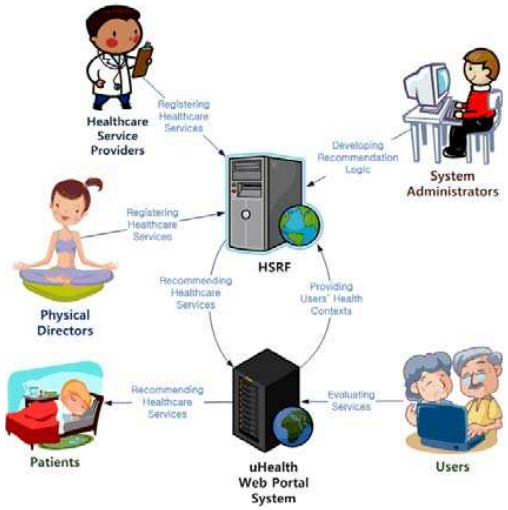

Figure 1. Context Diagram of HSRF

For more personalized recommendation of the services, HSRF applies user's health status to its recommendation process. Health status is the information about user's current health states or conditions, and it is the most important key to determine what specific services are suitable for the user. However, to use health status without any technical obstacle, the health status must be measurable and standardized. We extracted reasonable health status of users from the DCAP algorithm [1] which is our previous work for disease diagnosis.

As a mediator, HSRF manages complex interactions between healthcare service providers, consumers, and system administrators. Fig, 1 shows their relationships through the framework briefly. The healthcare service providers such as doctors, pharmacists, physicians, and physical directors can describe and register their own services on HSRF. Then, multiple recommendation mechanisms that are developed by the system administrators eventually search and recommend those registered services for the users. Users and patients can retrieve information about recommended services and evaluate them.

Interactions between HSRF and users are mediated by our previous research result called uHealth Web Portal System [2]. The web portal system provides various services and information about healthcare and also acts as an interface of HSRF for service consumers. The web portal actually triggers a recommendation process automatically delivering users' health status to HSRF; HSRF performs recommendation process with given users' contexts, and sends recommended results back to the portal.

B. *Framework Architecture*

We designed a flexible architecture of HSRF considering extensibility and scalability of the framework. Because, a brand-new type of service and health status can emerge at any time after the system is published, HSRF should require less effort to adapt those changes. Also, HSRF must be able to handle large amount of services and consumers. A consumer should be able to receive recommended results with high quality and low delay even if there are many services or requests from other consumers.

To meet requirements above, we adopted SOA (Service Oriented Architecture) design paradigm to HSRF. Healthcare services can be implemented using the Web Services technology and registered easily at runtime. Also, core logics for the recommendation can be realized to web services. For instance, we can imagine that there are number of web services available for hospitals and a recommendation web service that gathers and arranges the services of orthopedics only is deployed on the system. Likewise, there are recommendation web services that are in charge of their own categories and all the results from them are reorganized for users.

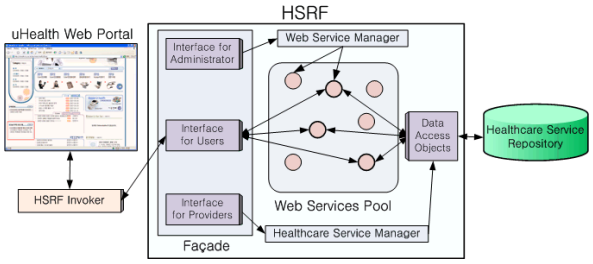

Figure 2. Architecture of HSRF

The entire architecture of HSRF is depicted in Fig. 2. HSRF consists of three types of modules: façade, core logic, and data access object. Façade modules are outer interfaces of HSRF. Each of them is connected to its core logic that performs the main functionality of the system. Core logic modules may need to use service repository to access information about healthcare services; data access object modules are wholly responsible for all transactions to the Healthcare Service Repository and provide handy interfaces to it.

There are three façade modules in HSRF: interfaces for healthcare providers, interfaces for users, and interfaces for administrator. Each of them is in charge of HSRF operations that aid each system user properly. Moreover, they can protect the framework from incorrect operations at the same time. Interface module for healthcare providers interacts with Healthcare Service Manager, interface for administrator is on Web Service Manager, and users' interface deals with Web Services Pool that is a set of various web services for healthcare service recommendation.

The data access object is a well-known module that is effective for handling database. HSRF puts all information about healthcare services into the database called Healthcare Service Repository, and all transactions to the repository must be performed through the data access objects only. It is such a common design pattern for handle the database to prevent damages of data from any unwilling database operations.

HSRF has two core logic modules for managing system: the Web Service Manager and the Healthcare Service Manager, and numerous web services for the recommendation logics in the Web Services Pool.

The Web Service Manager manages the Web Services Pool of HSRF enabling recommendation web services to be deployed and managed at runtime by the system administrators. The only parameter that is required for deploying a new recommendation web service is URL (Uniform Resource Location) of WSDL (Web Service Description Language) document of a new web service, and the system administrator can manage deployed web services using their URL as a primary key.

The Healthcare Service Manager provides various functionalities to manage the Healthcare Service Repository: registering a new healthcare service, modifying properties of the services, inquiring recommendation statistics, activating or deactivating the service, deregistering the services, and so on. The properties of a service are described in a XML (eXtensible Markup Language) document, and can be passed from the façade module to the Healthcare Service Manager to invoke registering or modifying function. To invoke other functions, unique global ID for the healthcare service is required as only parameter, and it is automatically assigned and returned after new service is registered.

Numerous web services in the Web Services Pool provide recommendation function which is a main logic of HSRF. The recommendation web services in the Web Services Pool should select proper healthcare services from the Healthcare Service Repository using user's contexts as a given input, and should arrange information about selected healthcare services. Each of the web services has its specialty on service category. For example, a web service selects nutritional remedies for the stress reduction, while another web service recommends oriental clinics for the stressed patients. Also, multiple services that have same recommendation target but different recommendation logics or required contexts of the users can be deployed.

Common points of these recommendation web services are input/output and name of function because multiple services should be invoked at once and recommended results must be able to be composed. Therefore, we defined XML Schemas to generalize input and output format of the recommendation web services (Fig. 3, Fig. 4, and Fig. 5).

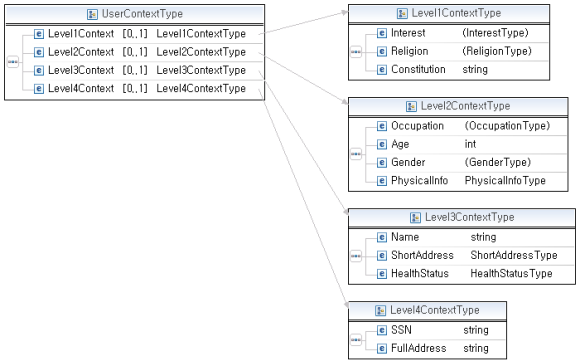

Figure 3. XML schema for input format of recommendation web service

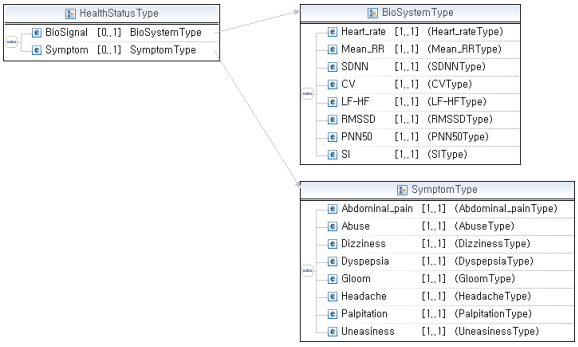

Figure 4. Health Status Type in Input XML schema

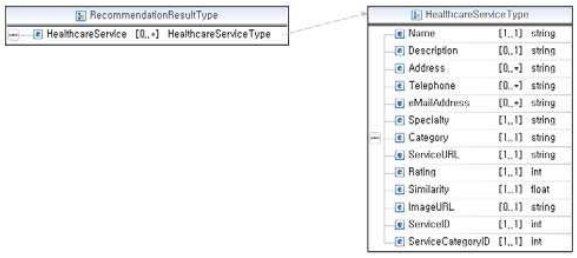

Figure 5. XML schema for output format of recommendation web service

In Fig. 3, the schema for input XML contains various elements for contexts of the service consumer dividing them into four security groups. Each group is declared as a complex type in XML, and some elements may not be present according to policies of consumer's privacy. Simple information likes interest or religion of a consumer is in level1 group, and more private information like age, gender, or occupation is in the second group. An element for health status, most important context, belongs to the third group and type of this element is 'HealthStatusType' which is described in Fig. 4. Inner elements of health status are largely divided into bio-signals and symptoms. Those elements are dependently selected by the uHealth Web Portal system that is able to collect and provide health status of user. It is also possible to add or remove elements dynamically and the framework can adapt those changes effectively.

The schema for XML output of recommendation web service contains information about multiple healthcare services. Sub elements of each service are name, description, service rating, service URL, and so on. Multiple healthcare services in output XML are arranged according to medical similarities with a consumer.

In addition to these recommendation web services, there are composing web services in the Web Services Pool that gather results from other recommendation web services and rearrange them into a single result. Rearranged results are finally passed back to the uHealth Web Portal, and the users can see the information about healthcare services in recommendation result.

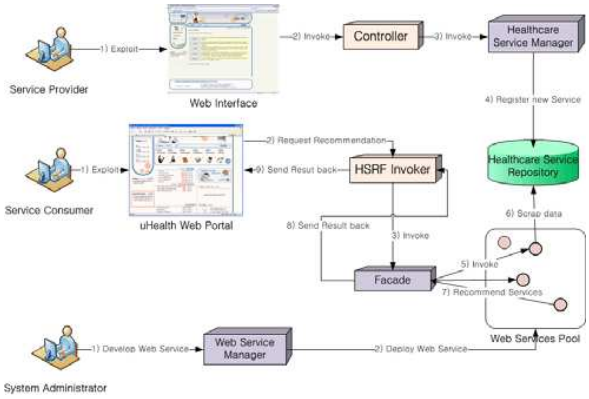

Figure 6. Successful process of all users in HSRF

C. *Framework Processes*

Successful processes of all users in HSRF are described at Fig. 6. Service consumers can retrieve a recommendation result through the second process in the Fig. 6. The first process in Fig. 6 is for the service providers who are able to register their own healthcare services to the framework, and the third process allows the system administrators to deploy a new recommendation web service onto the web service pool for the extension of the framework.

A process for the service consumers automatically starts during when they are using the uHealth Web Portal System, and they need some treatments from healthcare services. To start recommendation process, the uHealth Web Portal triggers a recommendation request to HSRF using the HSRF Invoker module. As an input of HSRF, a request message contains user's contexts including health status (Fig. 3). Passing through the façade module, the request is propagated to multiple recommendation web services in the Web Services Pool simultaneously. A detailed procedure in a recommendation web service is depicted in Fig. 7.

Invoked recommendation web service selects proper healthcare services among a specific domain comparing health status of user and properties of healthcare services. At the first phase of Fig. 7, web service extracts health status of user from input XML document, and arranges a health vector of that user, V_u. Then, in the second phase, web service also extracts properties of the healthcare services from the Healthcare Service Repository to prepare health vectors of service V_s. Unlike a user vector, V_s can be defined as a center of mass that is a mean point of health data set of users who got good treatments from a healthcare service.

After health vectors of user and healthcare services are prepared, distances between those vectors are calculated to identify medical similarities at the Phase 3 of Fig 7. Although, there are several methods to calculate a distance between vectors, web services basically adopted one of the simplest method that is called Manhattan distance calculation. In addition to the method, it is possible to adjust weight to each element of a vector to consider medical correlation between those elements which actually mean the health status. The following is an equation for adjusted Manhattan distance between a user vector, V_u and service vector V_s with weight.

$$\sum_{k=1}^{n} c_k \cdot | e_{u[k]} - e_{s[k]} | \quad (1)$$

$$where\ V_u = \{e_{u[1]}, e_{u[2]}, ..., e_{u[n]}\}\ and\ V_s = \{e_{s[1]}, e_{s[2]}, ..., e_{s[n]}\}$$

Because all elements of vector have their value as continuous decimal fraction, most of the services' vector will have different distances from vector for the user, but still some duplicated distance values may occur. In those cases, second arrangement at Phase 4 will be helpful.

Second arrangement of the healthcare services is performed at Phase 4 of Fig 7. Web service rearranges a recommendation result derived from Phase 3 according to other contexts of the

user such as age, gender, address, and occupation. For example,

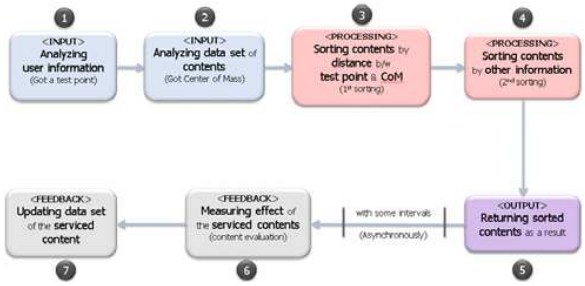

Figure 7. Inner process of recommendation web service

it is a quite nonsense to recommend hospitals for women to a little boy, or hospitals in New York to someone living in L.A.

A method to arrange proper healthcare services using the user's general contexts is similar to the method of common search engines. Web service treats properties and description of a healthcare service as a document and periodically tries to extract index terms from it. Then, it rates healthcare services comparing index terms of services and user's context as keywords. This second arrangement may prevent semantic faults of recommendation result. Moreover, as we mentioned above, it also can result more detailed order of the first result which may contains services that have same similarities.

A recommendation result which has been derived from Phase 3 and 4 of Fig 7 is sent back to the web service's invoker at the Phase 5. Result consists of information about the healthcare services such as services' name, description, URL, etc. and can be described using XML format (Fig. 5). It is returned to the façade module and eventually to the service consumers.

Results from multiple recommendation web services are gathered and reorganized, and finally sent back to the uHealth Web Portal System. The uHealth Web Portal system displays information about healthcare services that are recommended by HSRF analyzing retrieved XML result, and allows consumers to access and exploit those services directly using URL address or other access means.

After, healthcare services are recommended to a service consumer and he/she experiences good treatment from one of the services, the consumer may provide a feedback on the experienced service to the framework. At the Phase 6 in Fig. 7, feedback from the consumer is received, and at Phase 7, that feedback is updated into the database. More specifically, a log for the feedback from the consumer is recorded into the database at this time, and that log contains consumer's rating and health status when a recommendation for the consumer was being performed. A new log is immediately reflected to a next recommendation process that the exploited healthcare service involves.

The process for the service providers also starts from a specialized Web interface for registering healthcare services. This specialized interface lets the providers insert all information about a brand-new healthcare service, and sends it to HSRF. HSRF passes it to the Healthcare Service Manager that is supposed to insert a new service into the Healthcare Service Repository. Finally after the manager adds new service on the repository, it is possible to recommend the service immediately. A registering process for recommendation web service is similar to this provider's process. In this case, the Web Service Manager takes place of the Healthcare Service Manager, and deploys a new recommendation web service onto the Web Service Pool. Information about a new web service is in WSDL document that is developed by the system administrators.

IV. Implementation and Evaluation

To evaluate functionality and feasibility of HSRF, we present an example of recommendation process for service consumers that may occupy most of transactions of the framework. A recommendation process starts, as mentioned before, from the uHealth Web Portal system. The Web Portal system requests healthcare service recommendation for a consumer sending consumer's health status to HSRF. An input XML of the request that contains consumer's health status is in Fig. 8.

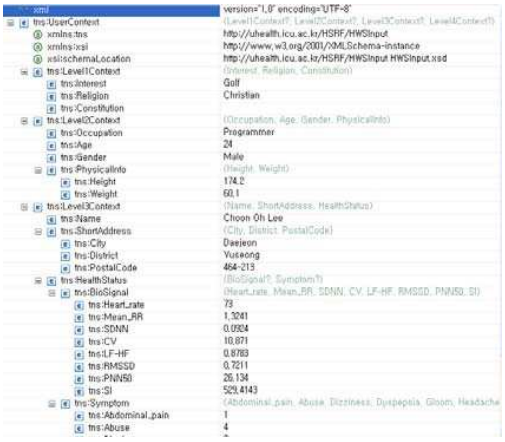

Figure 8. Example input of recommendation process

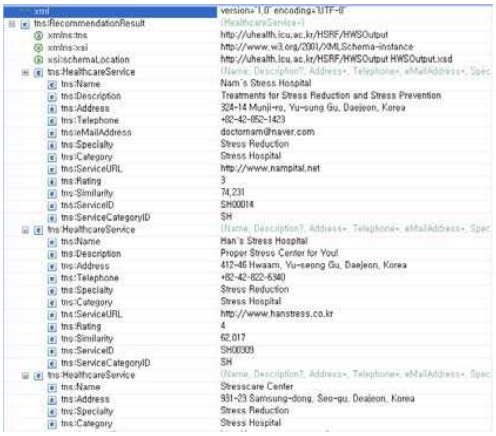

Figure 9. Example output of recommendation process

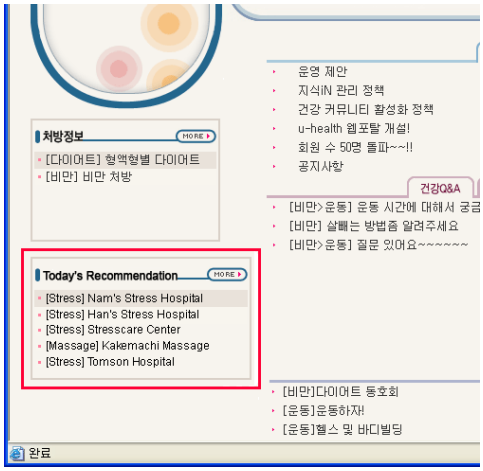

Figure 10. Recommendation result in uHealth Web Portal

HSRF receives the request, and passes it to multiple recommendation web services in the Web Services Pool. After simultaneous tasks of those web services, the framework gathers and rearranges results from them. Finally HSRF returns a composed recommendation result back to the Web Portal system (Fig. 9), and the Web Portal system displays information about recommended services to a consumer (Fig. 10).

From the implementation result above, we have confirmed that a recommendation process of HSRF works pretty well, and that a result for healthcare recommendation is valuable and reasonable to the consumers. However, more certain evaluation of the framework would be a statistical investigation on service consumers' satisfaction about recommendation results. Further evaluation of HSRF, which was difficult without large experimental group and long observation, will be possible when uHealth Web Portal is used by service consumers widely and frequently.

V. CONCLUSION

In this paper, we suggested a personalized healthcare service recommendation framework that considers consumers' health status to find adequate services for them. Our framework gathers information about service consumer's health status and calculates medical similarities between consumer and healthcare services automatically. Based on these similarities of each consumer, the framework arranges and recommends proper healthcare services. Also, we implemented HSRF and evaluated its functionality and feasibility. Although the evaluation was not fully certain to prove all approaches of this paper, we concluded that our framework is quite enough to provide better healthcare service recommendation to novice users and patients.

REFERENCES

[1] D.S. Han, J.S. Song, J. Matak, M.K. Lee, "A Probability-Based Prediction Framework for Stress Identification", 9th Internation Conference on e-Health Networking, Application, and Services, pp. 58-63

[2] D.S. Han, I.Y. Ko, S.J. Park, "An Evolving Mobile E-Health Service Platform", ICCE 2007, 2007.

[3] Bachus, Sonja C., Abreu, Michael J., Bachus, Jeff A., Wallace, Karen D., "Healthcare Provider Recommendation System", United States Patent, 20060015369, http://www.freepatentsonline.com/20060015369.html

[4] ABC Homeopathy, http://www.abchomeopathy.com/simplified.php

[5] Private Healthcare System, http://www.phcs.com

[6] US Healthcare Portal, http://www.ushealthcareportal.com

[7] Health-EU Portal, http://ec.europa.eu/health-eu/index_en.htm

[8] Onehealth.ca http://www.onehealth.ca/