An Integrated Approach towards the Homogeneous Provision of Geographically Dispersed Info-Mobility Services to Mobile Users

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Abstract. In this paper we introduce a mechanism enabling applications to present information retrieved from different services, thus delivered with different structure, in a homogeneous and seamless fashion. This mechanism was an outcome of the research that took place within the European Integrated Project ASK-IT. The project developed an ambient intelligence framework which supports mobility impaired people on the move to access context-sensitive information dependant on user geographic location and the use case under consideration. The information derives from geographically dispersed web services and is rendered on mobile devices. The ASK-IT framework enables the presentation of information that covers a wide variety of domains which belong to the info-mobility scope (Points of Interest, Route Guidance etc.). Our approach deals with the integration of information-providing services, in order to facilitate the homogeneity of the final presentation of the content, through the end-user application.

Keywords: Info-Mobility Services, Service Integration, Information provision, Web Services, Ontologies.

1 Introduction

As the world-wide stack of available services covering domains of the info-mobility scope constantly grows, challenges regarding the homogenization of the information retrieved have to be faced from modern HCI systems. A large number of Web services offer today online access to desired content through suitable software interfaces, thus solving interoperability problems between heterogeneous and distributed Internet-based applications. However, the structure of the content delivered differs between services that provide similar type of information.

Info-mobility services are usually consumed by systems that offer users on the move (and not only) information regarding Points of Interest, how to reach them etc.

M.J. Smith and G. Salvendy (Eds.): Human Interface, Part II, HCII 2009, LNCS 5618, pp. 385–394, 2009.

These systems usually have the ability to use combinations of different services, each of them offering different types of content, in order to cover the user needs as effectively and efficiently as possible. For example, in order to show a map to a user with a specific type of Points of Interest (e.g. Restaurants) around him/her, one such system must first invoke a service that provides information regarding Points of Interest and then, invoke a Mapping service, in order to get a map of the area around the user, with the Points of Interest drawn on it. Furthermore, in order for such a system to ensure the best Quality of Service (QoS) possible, it should have the ability to choose an appropriate service among different ones, which offer similar type of content and most probably belong to different providers.

The availability of more than one service for each type of required content ensures better Quality of Service delivered to the end users due to several factors. For instance, if different service providers are located in different countries, the seamless provision of location-aware information [1] to the end users becomes possible. This "geographically dispersed" approach towards effective service provision allows for the selection of the most appropriate provider every time retrieval of information is needed; regarding the Info-Mobility scope, the most appropriate provider (the one that will offer the best content) is usually the one that comes from the country of interest. Furthermore, very important is the fact that mechanisms which eliminate phenomena like "denial of service" are also applicable in the case where multiple service providers are used.

However, in the "multiple-providers" case, a major problem is introduced: Each provider delivers information within specific structures, which usually differ from the others'. As a result, the end-user application has to be able to "translate" the content retrieved by each provider to a form suitable for presentation on the client's device. In order to tackle with this "translation" requirement, we developed a mechanism to allow applications present information retrieved from different and heterogeneous services, in a homogeneous and seamless fashion. This mechanism is based on the use of ontologies that define a common vocabulary for available services, as well as a set of software wrappers with the goal to translate the service-specific data format to the common one defined by the ontology.

Currently, describing the semantics of Web services through the use of ontologies, are very active research areas. The W3C has launched the initiative to develop Semantic Web [2] and a semantic markup language for publishing and sharing ontologies; the Web Ontology Language (OWL) is being developed for this purpose. Also, there are a number of efforts for specifically describing the semantics of Web services. Two important initiatives have emerged in this respect: OWL-S and WSMO. OWL-S defines an upper ontology, that is, a generic "Service" class. Furthermore, the Web Service Modeling Ontology (WSMO) [3] is an initiative, which seeks to create an ontology for describing various aspects related to Web services, aiming at solving the integration problem. On the other hand, in order to achieve automated discovery, composition, and execution of Web services, the Web Service Modeling Language (WSML), which is a family of languages and which formalizes WSMO, is proposed. WSML is a formal language to write down annotations of Web services according to the conceptual model (WSMO). Logical inference-mechanisms can be applied to the descriptions in this language.

Work presented in this paper is an outcome of the research European Integrated Project ASK-IT [4]. The project developed an ambient intelligence framework which supports mobility impaired people on the move to access context-sensitive information dependant on user geographic location and the use case under consideration. The information derives from geographically dispersed Web Services integrated in the system by a "service alignment" process and is rendered on mobile devices. The user requirements elicitation process determined the services that should be supported in ASK-IT in order to fulfil the information needs of the users, which in our case are considered to be Mobility Impaired. These services are implemented as W3C Web Services [5], [6] offered by various providers throughout Europe. Several types of services are integrated in ASK-IT, and for each one of them, there are typically more than one provider - specific implementations. Different service providers may be located in different countries, thus making it possible to seamlessly provide location-aware information to the end users.

2 Architecture of the Integrated Service Provision Framework

The overall functionality of a system that wants to provide information regarding the Info-Mobility scope through Human-Computer-Interaction can be broken down in two separate parts, Information retrieval and Information presentation: the system should be able to invoke web services and then present the retrieved content to the users. As explained above, the system's ability to choose among different services of the same domain in a context-related fashion ensures better Quality of Service. However, due to the fact that each service has its own representation of the information provided, the system should have the capability to "translate" the information derived from each service, to a form suitable for presentation. This capability can be ensured from our proposed three-layer architecture depicted in Figure 1.

The main concept of our approach is the provision of a mechanism that acts like a middleware between the information retrieval and presentation components, facilitating homogeneity in the way information from different services of the same domain is presented. Within our proposed Framework, the end user application has

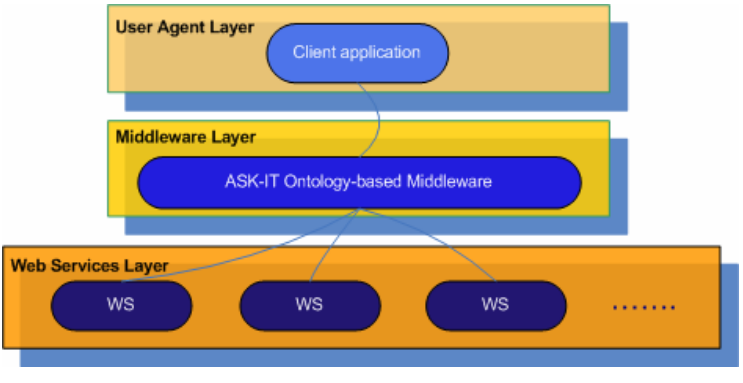

Fig. 1. The ASK-IT ontology-based Middleware

absolutely no idea of the actual representation of the information delivered upon the invocation of a real service. The only representations that it is able to understand are the ones defined within the system's Ontology. In our case, this refers to a collection of concepts and conceptual service models, able to cover the needs of information provision within the specific scope of interest.

2.1 The ASK-IT Ontology

The implementation of our approach was based on the "ASK-IT ontology" [7], which was developed within the ASK-IT project. Its development was originally motivated by the need to support the access to services and information for elderly and disabled users.

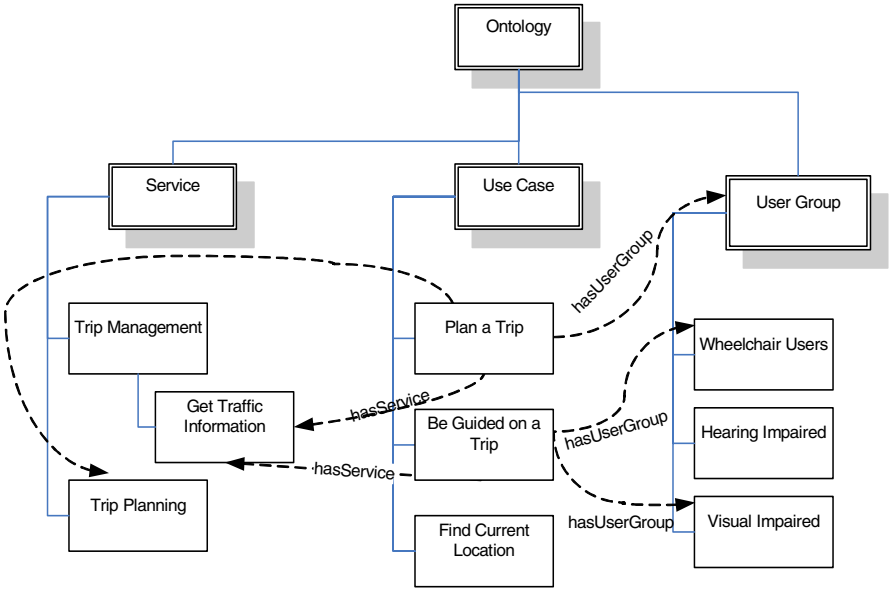

Fig. 2. ASK-IT Ontology snapshot

A snapshot of the ontology is depicted in Figure 2. It is divided into the following sub-ontologies:

- **Service Ontology.** This includes descriptions about the supported services, the supporting user groups, the supported use cases categories, as well as additional information related to the special needs of MI users.
- **Domain-specific ontologies.** These ontologies deal with the following application domains: a) Transportation, b) Tourism and Leisure, c) Personal Support Services Domain, d) e-Learning and e-Working, e) Social Relations and f) Community Building Domain.

The ASK-IT ontology has been developed by using the Protégé tool [8] and it is available in OWL-DL [9]. The ontology included more than 1400 concepts and 1100

properties. Within the ASK-IT ontology, various service models covering the needs of the domains of the Info-Mobility scope are defined, together with appropriate data types that represent the inputs and outputs of each service model. Each model's input and output is designed in a way so as for the service model to be adequate enough to carry and enable the presentation of information that covers the needs of the scope, with special attention given to the needs of mobility impaired users.

2.2 System Architecture

The middleware provided by our proposed framework acts like a bridge between the concepts defined within the actual services integrated for each domain and the ones defined within the ontology, thus providing the required "translation" mechanism of the information retrieved. This mechanism is lead by a "Service Alignment" process, which maps the concepts of every new service to the conceptual models defined within the ASK-IT Ontology.

Adopting an architectural model similar to the client-server, the ASK-IT ambient intelligence framework is divided in two main subsystems, the Server Side and the Client Side. The Server Side is responsible for the integration of the services that provide data and content, whereas the Client Side includes all modules that are responsible for handling interaction with users and manipulating data and content received upon request from the Server Side. The communication between these two subsystems is utilized through the exchange of messages between software agents. Several types of agents reside in both the Server and the Client Sides of the framework.

The service alignment process constitutes the cornerstone of our approach towards the homogeneous service provision. This procedure maps each integrated service to the appropriate ontological concepts, which are in turn used within the rest of the application for the proper presentation of the content delivered to the end users. In specific, each "real" service is mapped to a specific service model defined within the ontology, and the data types of the actual inputs and outputs of the "real" service are mapped to the appropriate ontological concepts that constitute the inputs and outputs of the respective model. Supplementary information regarding the real Web Service is also stored during the process (Geographic Location of the provider, etc.), enabling the system to choose -each time retrieval of content is needed- the best service to invoke.

Fig. 3 depicts the interoperations occurring between the basic modules of the Server Side, as well as any external actors or any other layer components. The Data Management Module (DMM) aims at developing an automatic mechanism for aggregating information originated from multiple service content providers. The end-user requests, through a user interface docked on the Client Side subsystem, (desktop application, mobile phone, PDA) invoke a specific service through a personal user-agent, which in turn requests the service from a broker agent after being translated in a machine-readable format. The actual role of the DMM is to listen to the request, decompose it, perform ontology-based search for the appropriate services and finally return the requested information back to the user.

From a technical point of view, the input of the DMM is an invocation request for a specific ASK-IT ontological "service model". Based on the information stored during the service alignment process, the "service model – based" request is translated within the DMM to invocation requests that are proper for actual services. This in fact

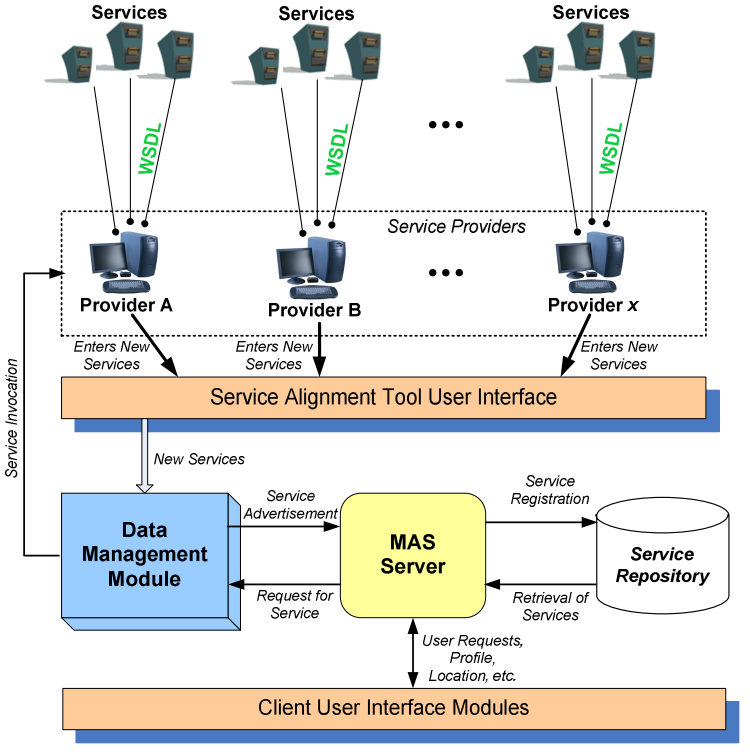

Fig. 3. The ASK-IT Server-Side Overall Architecture

means that the DMM takes the content of the "ontology-based" input, translates it properly and then puts it inside a structure that is appropriate for the invocation of the actual services. The inverse procedure takes place after the response of an actual service; the returned content is taken from the response's structure and is put inside the one defined by the ontology's specific service model's output.

As a consequence, the user agent application does not need to have any knowledge over the actual services invoked and the data structures needed for the actual service invocation. It just communicates with the ASK-IT middleware by the means of the service models and the ontological concepts defined within the ASK-IT ontology. These concepts and models are on one hand adequate for the invocation of all the services of the various domains of our scope of interest, and on the other, appropriate for the presentation of the content derived after a service invocation.

3 The ASK-IT User Agent Application

Our developed user agent is a mobile application for PDA devices that consists of a set of individual modules, each one responsible for the effective and efficient presentation of content regarding one specific domain of interest. In Fig. 4, the modules regarding Indoor / Outdoor localization (a, b) and route guidance (d, e) are

Fig. 4. The ASK-IT User Agent Application

depicted, together with the modules responsible for the functionalities of searching for Points of Interest (c), Social Events (f), E-Learning (g) and E-Working (h).

The modules that constitute the end-user application were designed on the basis of the user needs regarding each domain of interest, and their integration focuses on the provision of seamless user interaction. Each module was designed in a way so as to provide the best possible utilization of the capabilities that were offered by the service models defined within the ASK-IT ontology. Special attention was given to the fact that all the information which was capable to be delivered (as input or output) through the service models should be able to 1) be provided from the end users and 2) be presented to them in the most effective and efficient way.

At this point it is obvious that the end user application of our approach relies heavily on the quality of the ontology used within the proposed system. The amount of information that can be delivered through our end user application depends of course on the amount of content that can be retrieved from the invocation of the actual, integrated services, but could as well be constrained from a possible lack of "completeness" in the ontology being used within the system.

4 Experimental Results

The ASK-IT project was supported by 8 pilot sites, dispersed among cities throughout Europe: Athens and Thessaloniki (GR), Madrid (ES), Bucharest (RO), The Hague (NL), Nuremberg (DE), Genoa (IT), Helsinki (FI) and Newcastle (GB). In order to test and evaluate the overall ASK-IT framework, each site provided Web Services, which were integrated in the ASK-IT system, by the means of our service alignment process.

The concept of our experimental sessions was to evaluate whether our approach is capable to provide sufficient information seamlessly when users move from country to country and use different service providers for content retrieval. Within this context, we had to evaluate:

1. The overall usability of the system
2. The sufficiency of the information delivered
3. The preservation of the system's usability when moving from country to country
4. The preservation of the sufficiency of information delivered when moving from country to country

Table 1. Number of Services Integrated and tested per application area

Service	Number of Services aligned, integrated and cross-site tested
Search for Points of Interest	10
Multimodal Route Planning	7
Social Events	5
E-Learning	2
E-Working	2
Domotics management	3
Health and Emergency	2
Mapping	3

For this purpose, we drew upon the ASK-IT pilot sites and their user - testing sessions, organized by the ASK-IT consortium and all of the pilots in the supporting cities in order to evaluate the ASK-IT project's outcomes. Within these sessions, mobility impaired users coming from all the supported sites tested and evaluated the system. Since each pilot site had provided services for a number of the domains of interest, the users could use services for each domain, from several different providers, in several different geographic locations.

The tests were divided in two different types of sessions. First, the overall usability of the system, together with the sufficiency of the information delivered was evaluated in "stand-alone" testing sessions. These were sessions organized by each pilot site separately, within which users coming from the specific site evaluated the system for the case where information derived from the providers of the same site. For example, during the Greek site stand-alone tests, Greek users evaluated the ASK-IT Framework in Greece, by using the information provided by the Greek service providers. The second type of sessions organized was the "cross-site" tests, within which users evaluated the ASK-IT Framework by using services from several different providers,

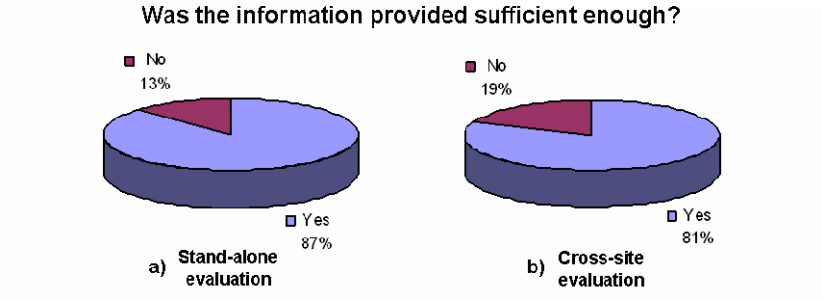

Fig. 5. Evaluation Results regarding the sufficiency of information delivered

in several different geographic locations. These sessions provided feedback regarding the preservation of the system's usability and the sufficiency of the information delivered when the users are moving from country to country.

Questionnaire-based short interviews and "think aloud" protocols were used in both the stand-alone and cross-site tests, in order to record the user's opinion regarding the outcome of our approach. During the stand-alone tests, 70 users evaluated the ASK-IT framework within sessions organized in all of the sites. The users stated in general that the overall application was usable (at a percentage of 93%), and the information delivered was sufficient enough at a percentage of 87% (Fig 5.a). Some of the users (21 individuals) that had already tested the application within the stand-alone tests evaluated our approach's outcome during cross-site testing sessions.

At the cross-site evaluation, the majority of the users stated again that the application was usable, in a percentage (95%) very close to the one that came from the stand-alone tests. This was an expected result, since the end-user application and the way it presents information was due to our approach the same, regardless the providers used for information retrieval. Thus, the users could find the information they were looking for exactly at the same place that it was residing during the stand-alone tests. Regarding the content delivered in this case, the users again stated in general that it was sufficient enough, at the high percentage of 81% (Fig. 5.b). However, it is obvious that the percentage in this case was a bit lower than the respective percentage of the stand-alone tests.

The latter was more or less an expected finding too, given the fact that during the cross-site testing sessions the users were located at a city that was an unknown environment to them (simulating a user's travel to a different country than his/her own), compared to the cities of the stand-alone tests, which in most cases were the ones that the users lived in. As a consequence, during cross site testing, the users had increased needs regarding the amount and the detail level of information delivered. According to the users' opinion, these increased needs were masked to an extent due to 1) the homogeneity of the content delivered during the stand-alone and cross-site tests and 2) the fact that the information was presented from exactly the same user interface of the end user agent, which they had already used during the stand-alone tests. As a result, the difference between the percentages of the satisfied users from the sufficiency of the delivered information, between the two types of testing sessions, was kept at a significantly low level (6%).

The results of the pilot studies indicated that users usually need more detailed information from an info-mobility services system, when they are moving within an unknown environment, than when they are inside an already familiar one. However, the fact that the information provided from our approach is given to the users in a homogeneous fashion, regardless their location and the service provider used, improves their understanding of the content derived from a location-aware information provisioning system. Furthermore, in a few cases service providers indicated that they could offer through their services more information than our ontology could handle. The degree of detail of the information delivered from our approach relies heavily on the detail level of the ontological concepts used within the middleware used. Thus, it is absolutely essential for a proper implementation of such frameworks to use ontological concepts of a good detail level, that cover the scope of interest in a way as complete as possible.

Concluding, the analysis of the testing sessions' outcome indicated that our approach's ontological middleware for the homogenization of content derived from info-mobility services, prior to its delivery to end users, enhances the capabilities of a system regarding the provision of location-aware information. This approach allows for large amounts of similar services to be integrated, in order for the system to be able, each time information is needed to select the best content source to be used, thus ensuring the best Quality of Service (QoS) possible.

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