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A BOTTOM-UP ONTOLOGICAL APPROACH FOR HETEROGENEOUS WEB SERVICES INTEGRATION AND THEIR USAGE SEMANTICS REPRESENTATION

Evgeniya Ishkina, *PhD student, Astrakhan State University, 20a, Tatischeva st., 414056 Astrakhan, Russia, e-mail: ishkina@aspu.ru.*

Serge Miranda, *professor of Computer Science, Director of MBDS Master degree, University of Nice Sophia Antipolis, Bâtiment IUP, 3735 route des Dolines, Sophia Antipolis, 06560 Valbonne, France, e-mail: serge.miranda@unice.fr.*

A bottom-up ontological approach for integrating heterogeneous web services and their incremental usage semantics representation is described. The results of comparative analysis of our proposed ASTRA approach with other related ones in appropriate research fields, are provided. Formal model of proactive information system corresponding to this ASTRA approach, allowing creation of a smart intermediate layer between a set of heterogeneous web services and end-user applications based on them, is presented. This proactive information system is being implemented as middleware, and its multilayer architecture is also decribed. This ASTRA software allows solving the following issues in mobiquitous information systems: services usage situation analysis, detection of useful services patterns (heuristics for solving typical user tasks), and also services search and generation for any given situation. Thus it helps to provide users with services which are more appropriate to concrete usage situations. Finally conclusion and outcome of our ASTRA project along with future research directions are given.

Key words: *service computing; middleware, service composition, service mining, data mining, situation awareness, context awareness.*

Ишкина Евгения Геннадиевна, *аспирант, Астраханский государственный университет, 414056, Россия, Астрахань, ул. Татищева, 20а, e-mail: ishkina@aspu.ru.*

Миранда Серж, *профессор, директор магистерской программы MBDS, Университет Ниццы Софии Антиполис, Bâtiment IUP, 3735 route des Dolines, Sophia Antipolis, 06560 Valbonne, Франция, e-mail: serge.miranda@unice.fr.*

Описан онтологический подход к восходящей гетерогенных интеграции веб-сервисов и инкрементному представлению семантики их использования. Приведены результаты сравнительного анализа подхода, предлагаемого в проекте ASTRA, с другими работами в исследуемой области. Представлена формальная модель проактивной информационной системы взаимодействия, реализующей данных подход и позволяющей создать интеллектуальный промежуточный слой между множеством разрозненных веб-сервисов и приложениями на их основе для конечных пользователей. Данная проактивная информационная система взаимодействия в настоящее время реализуется в виде промежуточного программного обеспечения, многоуровневая архитектура которого также описана в статье. Данное программное обеспечение решает следующие задачи: анализ ситуаций использования сервисов, обнаружение устойчивых композиций сервисов (эвристик для решения типичных задач), а также поиск и генерацию сервисов для заданной ситуации. Таким образом, это позволяет предоставлять пользователям сервисы, наиболее подходящие для конкретной ситуации использования. И наконец, сделаны выводы об области применения полученных результатов и о планируемых направлениях дальнейших исследований.

Ключевые слова: *сервисные вычисления, промежуточное программное обеспечение, композиция сервисов, интеллектуальный анализ данных, ситуационно-зависимые системы, контекстно-зависимые системы.*

1. INTRODUCTION

ASTRA project is being developed in Astrakhan State University since 2010 and its global functional architecture was presented in [1]. We focus here on the multilayered architecture of the middleware allowing a bottom-up ontological integration of heterogeneous web services which is being developed in the framework of our ASTRA project. ASTRA goal is to improve user interactions with *mobiquitous* information systems in areas of tourism, education, university management using adaptive service-oriented approach. *Mobiquity* refers to *mobi*lity of the cell phone becoming a computer (smartphone) and ubi*quity* of Internet becoming broadband in the pocket and 2.0 [3].

Basic rationale of ASTRA project is that it is necessary to collect knowledge about usage in distributed heterogeneous mobiquitous systems. This knowledge should represent strategies of goals achievement in particular situations. Users no longer want to get isolated information; they look for complex services. Current systems are becoming task-aware: their goal is to match high-level user task in a transparent manner. Services could then be recombined for producing new ones with the possibility to evaluate important characteristics of service composition and its usefulness in particular situations.

The remainder of this paper is organized as follows. In section 2 we present a brief survey of related work and the position of proposed ASTRA approach. Then in section 3 we give the formal definition of a proactive interaction system implementing the bottom-up services integration approach and we describe layers of the middleware implementing proactive interaction system for mobiquitous information systems. And, finally, we give some research directions to enhance and validate our proposal.

2. RELATED WORK

As result of analysis of related work we consider three main groups of approaches for intelligent service composition: approaches for context-aware service composition; approaches for goal-driven service composition; approaches for pattern-driven service composition. Description of some projects in each group is given in [1].

Approaches for context-aware and goal-driven composition are often clearly separate; however there exist some mixed approaches [4]. The majority of approaches for pattern-driven composition are not context-aware. Patterns represent result of an attempt to find context-free service sequences.

In [5] two approaches for service composition are defined: top-down approach when composition of existing web services is driven by specific search criteria, and bottom-up approach when interesting and useful compositions of existing web services are discovered with no such criteria.

Semantic web services are only related to context-aware and goal-driven approaches and they are always built in a top-down way. In the proposed proactive interaction system the bottom-up approach consists in service mining correlated with services dependencies mining, and in incremental services integration on operational, compositional and situational levels [6].

3. PROACTIVE INTERACTION SYSTEM ARCHITECTURE

An interaction system [2] is a system which is able: to collect data about situations of services usage by end users, to deduce knowledge about usual services usage situations based on analysis of user interaction with an information system; this knowledge represents multidimensional metadata: static/dynamic user profile parameters, “external” context information (space, time, environment, etc.) and user goals, to select appropriate services for the given usage situation.

Formally an interaction system can be defined as a multi set $\langle S, C, L, A, F_L, F_C, F_R \rangle$, where:

– S is a set of all available services which could be “internal” mobiquitous information system services or external ones;

– C is a set of available sources of situational information (hereinafter referred to as sensors) allowing to get situational constraints for user sessions. These sensors can be defined at interaction system level (subset $C_I \subseteq C$), at user environment level (subset $C_U \subseteq C$), and they also can be external independent sensors (subset $C_E \subseteq C$);

– L is a set of interaction logs, i.e. logs of services calls along with concerned sensors data;

– A is a set of services annotations by situational constraints;

– F_L is a function of producing new situational service annotations or refining existing ones by analysis of interaction logs (L). Thus $A' = F_L(A, L)$ is an updated set of services annotations by situational constraints;

– F_C is a function of producing high-level situation description on the base of initial sensors data;

– F_R is a function for obtaining appropriate services (S_c set) from the set of available ones (S) using their situational annotations and situation description for the given user session (c). Thus $S_c = F_R(S, A, c)$.

Proactive interaction system [3] is an interaction system aiming at the collective service intelligence management, mining new useful service compositions corresponding to high-level user tasks and generating for the specific usage situation a unique service from available fragments

Formally a proactive interaction system (fig. 1) can be defined as a multi set $\langle S, C, L, A, F_L, F_C, F_R, F_S \rangle$, where:

F_S is a function of producing new stable service compositions on the base of the set of available services (S) by analysing interaction logs (L). Thus $S' = F_S(S, L)$ is an updated set of available services.

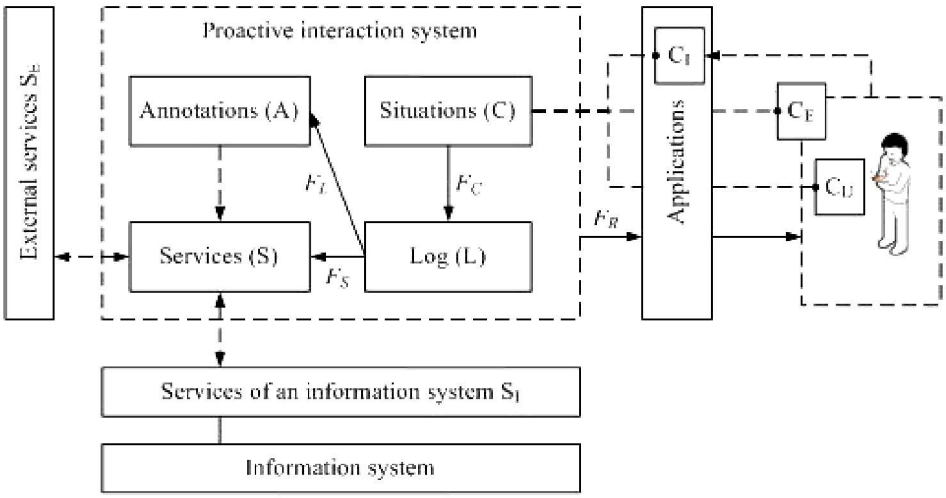

Fig. 1. Proactive information system

3.1. Integration layer

In fig. 2 the functional scheme of this layer is presented.

WSML (Web Service Modeling Language) [10] was selected for representing the unified service metamodel [6]. It is due to the fact that its expressiveness meets the requirements defined in [6] and there exist tools for editing WSML services descriptions and an environment for invoking the described services. WSDL 2.0 [8] was selected for representing services operational syntax required for automatic services invoking. It allows representing syntax of SOAP services as well as of RESTful services which are not provided with any description initially.

The developed software prototype allows integrating SOAP and RESTful services, these are non-semantic web services. The possibility to integrate semantic web services is also demonstrated on the example of SAWSDL services. The next step is to realize special mediators for integrating other semantic web services: SA-REST, OWL-S, WSMO, etc.

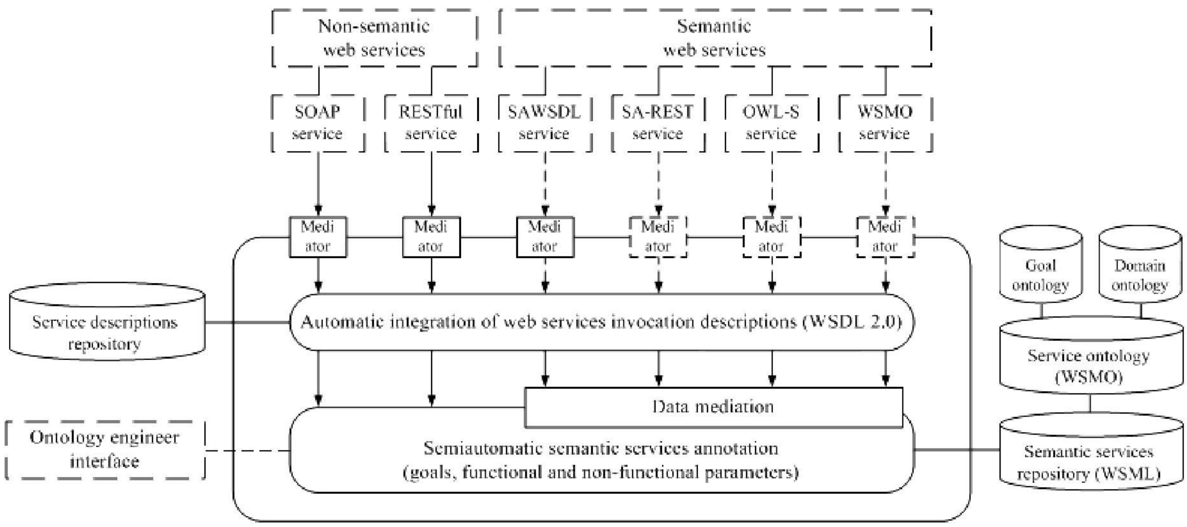

Fig. 2. Integration layer

Each service which is to be integrated in the service warehouse should be annotated by the basic semantic profile including description of its goal and also of its functional and optionally non-functional parameters. This profile is represented in WSML language based on WSMO service ontology which uses the common goal ontology and domain ontology. The last one allows describing service parameters semantics.

When integrating semantic web services using external ontologies terms the correspondence between internal and external ontologies terms should be established. It is implemented using mediation units. This process is partly automated but it needs ontology engineer intervention.

3.2. Interaction analysis layer

In fig. 3 the functional scheme of this layer is presented.

Situation recognition unit is implemented using multiagent approach. Collecting situation parameters is realized using the set of formally described logical and physical sensors. Procedure of retrieving data from sensors can depend from the data coming from other sensors. Each sensor is considered as a function returning a scalar, a nominal or character value, or a vector of values of one of these types. For each sensor a finite or infinite set of its possible values is defined.

Sensors are used to obtain situation parameters based on context and user ontologies. Data harmonization and queries parallelization are needed, and it is naturally implemented in the multiagent approach in which each sensor is provided with a corresponding agent.

An application programming interface (API) is implemented for connecting middleware with end-user applications. Multiple applications can use the same middleware and thus the same warehouse of services and context-aware patterns (heuristics). Each application can define its own set of situational sensors. Using this API an application can store information about user activity (interaction log), query for services which are the most appropriate for the given situation and invoke services.

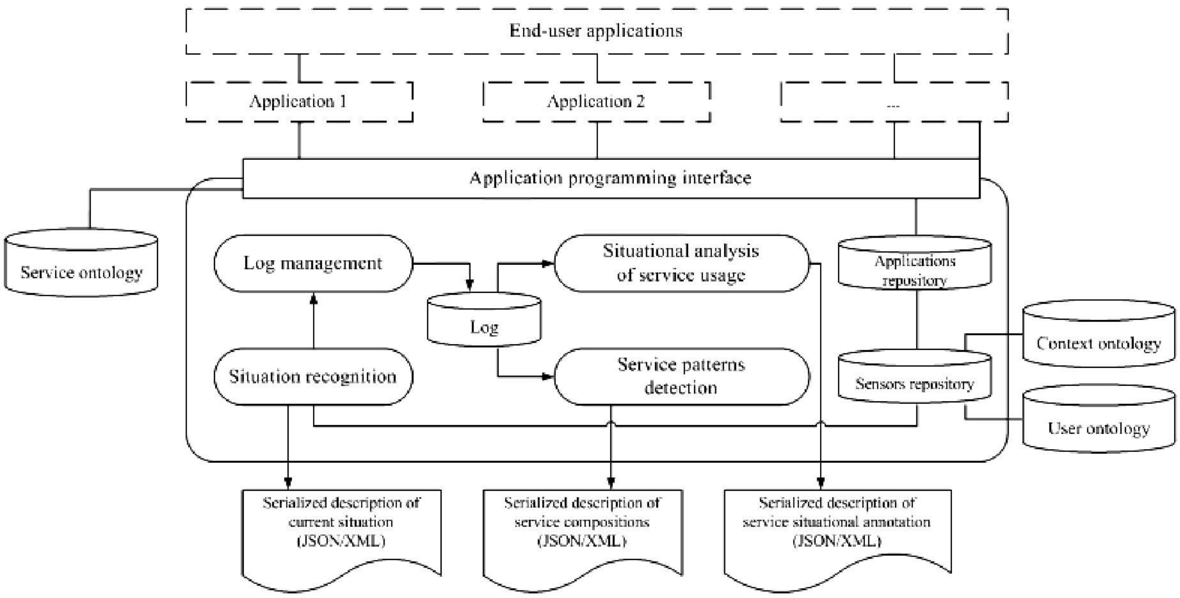

Fig. 3. Interaction analysis layer

3.3. Service warehouse management layer

In fig. 3 the functional scheme of this layer is presented.

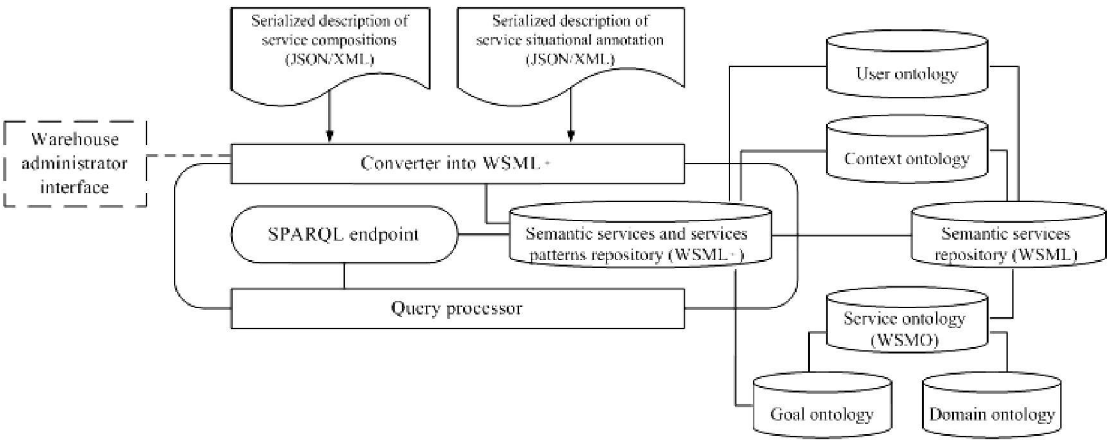

Fig. 4. Service warehouse management layer

An extension of WSML language called WSML+ was developed for representing situational annotations of service compositions.

This layer interacts with the interaction analysis layer. Descriptions of detected heuristics (service compositions) and service annotations are converted into WSML+.

This layer also processes search queries for appropriate services. Queries are formulated using goal, domain, user and context ontologies. SPARQL [7] endpoint is used for queries processing.

3.4. Situational service generation layer

In fig. 5 the functional scheme of this layer is presented.

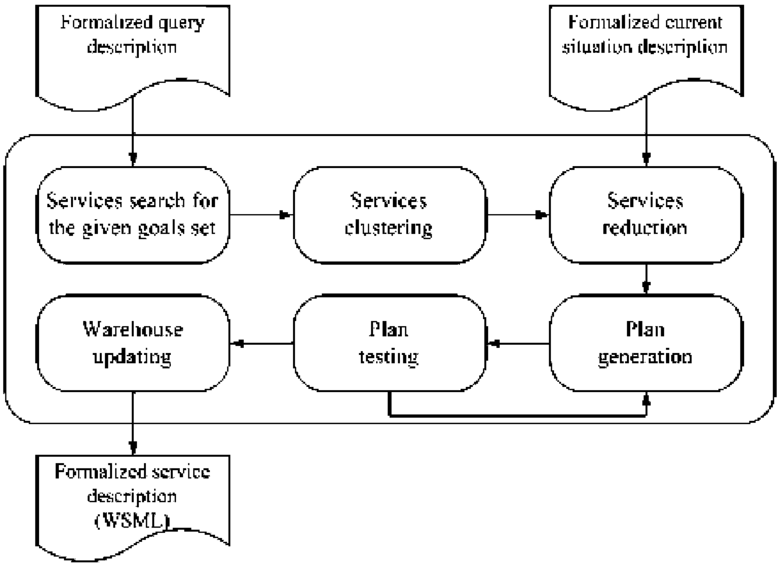

Fig. 5. Situational service generation layer

The result of situational service generation is its simplified description in WSML without WSML+ features because the generated service represents just a services sequence without situational annotations.

The end user receives a list of services recommended for his situation order by descending of their relevance.

3.5. Service invocation layer

This layer is build on the top of service integration layer. Service invoking and communication with end-user applications is implemented using WSMX (Web Services Execution Environment) [9].

4. CONCLUSION

In this paper we presented a bottom-up ontological approach for heterogeneous web services integration representing the base of a proactive interaction system within our ASTRA Project. We outlined salient features of our ASTRA architecture with a focus on its middleware implementing this proactive approach.

Our future research within ASTRA concerns optimization of the ontology reasoning algorithms for service mining and automatic composition of services fragments into a final service.

The proposed ASTRA approach is being implemented and validated for mobiquitous touristic cultural paths in the City of Astrakhan (Russia) using tags in the real world which could be scanned (QR Code) or touched (NFC tags) to get multimedia information on the cell phone becoming a guide in the pocket.

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ПЕРЕРАСПРЕДЕЛЕНИЕ ИНФОРМАЦИОННЫХ ПОТОКОВ В УЗЛАХ РАСПРЕДЕЛЕННОЙ МУЛЬТИАГЕНТНОЙ СИСТЕМЫ ОБРАБОТКИ РАЗНОРОДНОЙ ИНФОРМАЦИИ

Приходько Максим Александрович*, кандидат физико-математических наук, Московский государственный горный университет, 119991, Россия, г. Москва, Ленинский проспект, д. 6, e-mail: spex19@mail.ru*

В статье рассматривается задача оптимального перераспределения информационных потоков в распределенной системе обработки разнородной информации в условиях непредсказуемого изменения объемов входящих информационных потоков. Показано, что оптимальность перераспределения информационных потоков разнородной информации определяется загруженностью доступных узлов и качеством каналов связи с ними. Предложено выбор узлов для перераспределения излишков нагрузки делать на основе весов, равных отношению доступной емкости узла к скорости передачи данных по каналу связи. Выбираются узлы с наименьшими весами, суммарная емкость которых не меньше перераспределяемого излишка. Дальнейшее перераспределение производится в случае наличия дополнительных доступных узлов или неполного использования емкости узла с наибольшим весом среди выбранных. Приводится алгоритм перенаправления информационных потоков.

Ключевые слова*: обработка информации, система обработки информации, мальтиагентная система, распределенная система, агент, контрагент, интеллектуальные агент, конкурирующие агенты, информационный поток, перенаправление, разнородная информация, оптимизация, узел, разнородная информация.*