Personalized access towards a mobile neuroscience

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Abstract

A crucial requirement for the context-aware service provisioning is the dynamic retrieval and interaction with local resources, i.e., resource discovery. The high degree of dynamicity and heterogeneity of mobile environments requires to rethink and/or extend traditional discovery solutions to support more intelligent service search and retrieval, personalized to user context conditions. Several research efforts have recently emerged in the field of service discovery that, based on semantic data representation and technologies, allow flexible matching between user requirements and service capabilities in open and dynamic deployment scenarios. Our research work aims at providing suitable answering mechanisms of mobile requests by taking into account user contexts (preferences, profiles, physical location, temporal information…).

In recents works, we have built an ontology, called O'Neurolog, to capture semantic knowledge a valuable in Neurology domain in order to assist users (doctor, patient, administration …) when querying Neurology knowledge bases in mobile environment.

This current paper focuses specifically on answering mechanisms when accessing to neurological data stored on mobile devices. We present some insights in order to overcome the problem of semantical and personalized access by using similarity between Trees formalizing user needs/requests and available neurological resources.

Keywords : Neurology; ontology; context-aware; semantic web; query answering; mobile environment.

1. Introduction

1.1 General context

In context-aware information provisioning scenarios, it is crucial to enable the dynamic retrieval of available knowledges in the nearby of the user's current point of attachment, while minimizing user involvement in information selection. Data and knowledge discovery in pervasive environments, however, is a complex task as it requires to face several technical challenges at the state of the art, such as user/device mobility, variations (possibly unpredictable) in service availability and environment conditions, and terminal heterogeneity.

Users might need to discover knowledges whose names and specific implementation attributes cannot be known in advance, while data providers need to use several and different terms or keywords and whose technical capabilities and conditions at interaction time might be mostly unpredictable beforehand.

In medical domain, there is a great need for using mobile devices to access and retrieve neurological data concerning a patient by physicians or interested organisms (insurance, emergency …). Neurological information is available via web pages, stored in ftp sites or relational databases, and textually described in publications. Neurology (from Greek, neuron, "nerve"; and logia, "study") is a medical specialty dealing with disorders of the nervous system. Specifically, it deals with the diagnosis and treatment of all categories of disease involving the central, peripheral, and autonomic nervous systems, including their coverings, blood vessels, and all effectors tissue, such as muscle.[1] The corresponding surgical specialty is neurosurgery. A neurologist is a physician who specializes in neurology, and is trained to investigate, or diagnose and treat neurological disorders. Pediatric neurologists treat neurological disease in children. Neurologists may also be involved in clinical research, clinical trials, as well as basic research and translational research.[2]

However, mobile search engines are unable to answer questions about this massive neurological knowledge base other than identifying resources that contain some subset of the specified attributes. The main reason for this limitation is that the representation of biological information on the web is not machine understandable, in the sense that computers cannot interpret words, sentences or diagrams so as to correctly reason about the objects and the relations between them that are implicitly stated in those documents [3]. The primary goal of the semantic web is to add semantics to the current Web, by designing ontologies which explicitly describe and relate objects using formal, logic-based representations that a machine can understand and process [4]. This ongoing effort is expected to facilitate data representation, integration and question answering, of critical importance in the life sciences and hospital information system (HIS).

Therefore, returned answers scope needs to be filtered according to finer-grained criteria other than administrative or network grouping. All and only those data that are semantically compatible with the user's context should be automatically and transparently made visible to him. The exploitation of user's context-awareness in knowledge discovery helps mobile clients saving time and efforts in information retrieval.

On the other hand, the potential of semantic-based discovery has not been fully exploited yet because of various management issues, which seem to be still open. Access terminals usually exhibit relevant differences in resource capabilities, such as display size and resolution, computing power, memory, network bandwidth, and battery. A crucial management crucial issue remains how to provide support for semantic-based discovery to mobile devices with limited capabilities. Semantic support services, e.g., ontology repositories, inference engines and knowledge management tools, typically require a large amount of computational/memory resources that may not fit the properties of mobile devices. In particular, strict limitations exist about the kind of semantic support facilities that can be hosted on resource-constrained devices. For example, executing a reasoning process on board of a resource-limited device, such as a smart phone, might not only consume battery, but more important, it would probably monopolize all available memory resources, thus making the execution of other applications very difficult.

1.2 Runing example

Let us suppose a physician who needs to consult a patient's clinical data in order to set a proper treatment for him. If the healthcare act is taking place inside the hospital, the doctor will be allowed to access the Hospital Information System (HIS) and to retrieve all the patient's Electronic Health Records (EHRs). Having enough time and knowledge – and depending on the usability of the software system – the specialist will rule out all the useless pieces of information and will get the ones he is interested in.

In the latter situation, a brief report including those pieces of the patient's clinical data which ought to be considered would be very valuable. The clinical procedure which is going to be carried out would determine which data should be part of this summary. For example, is an another member of the patient's family has the same symptoms yet. If true the physician could propose muscular or hepatic biopsy and so realize lumbar punctures, cerebral scanner or IRM.

The patient does not walk, does not stand nor sitting does not his head. He/she did not speak, but knows how to understand, she established contacts with people who are very familiar.

We think that by joining context to domain knowledge could help improving the summarization of research results for a mobile user. This activity is called personalization and implies recommendations.

1.3 Paper organization

The remaining of this document is structured as follows. Section II presents a recommender System. The vision of Semantic Web in neuroscience domain is presented in Section III. In Section IV, we propose a semantic and personalized strategy based on answering mechanisms from mobile devices. Section V is devoted to giving some steps of building a prototype called NeuroService 1.0. Finally, in Section VI some conclusions and directions for future work are pointed out.

2. what's a recommander system ?

As shown in Fig. 1, a recommender system can be running either remotely in a server, or locally in a fixed or mobile consumer device. In both scenarios, the personalization tool selects automatically items that match the users' preferences and needs, which are previously modeled in their personal profiles. In current approaches, the profiles store items which are (un)appealing to the users, along with their main attributes (named content descriptions) and their ratings (i.e., the user's levels of interest). These ratings can be explicit or implicit. In the first case, users are required to explicitly specify their preferences for any particular item, usually by indicating a value in a continuous range (e.g., [1, 1]). Negative values commonly mean disliking, while positive values express liking.

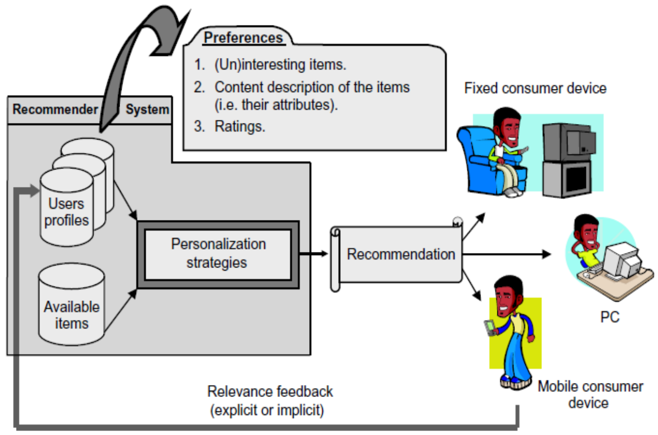

Figure 1. An overview of a recommender system

As explicit ratings impose additional efforts on users, recommender systems can also infer information about their interests from their behavior in a much less obtrusive way. Typical examples of implicit ratings are purchase data, reading time of Usenet news, and browsing behavior [5]. Owing to the difficulty of acquiring explicit ratings, some providers of recommendation services adopt hybrid approaches: they compute recommendations based on explicit ratings whenever possible; in case of unavailability, inferred implicit ratings are used instead.

Once the user's preferences have been modeled, the recommender system elaborates suggestions by resorting to different personalization strategies. After a recommendation is received, the user can provide information about its accuracy in an explicit or implicit way, analogously to what we have just explained before.
As shown in Fig. 1, that information (commonly named relevance feedback) allows the recommender system to update the user's profile, and therefore, to adapt the offered suggestions to the changes in his/her personal preferences.

In order to decide whether a given item must be suggested to a user, some personalization strategies compare its attributes with those defined in his/her profile, whereas other techniques miss these content descriptions and only consider the ratings assigned by the users to their preferences. All of these strategies have a common drawback in the fact that the recommendations are made by syntactic mechanisms, which disregard a huge amount of knowledge that may be hidden behind the semantics (i.e., meaning) of both the items' content descriptions and the user's preferences.

Such a limitation reduces the quality of the suggestions offered by the current recommender systems and, besides, originates most of the weaknesses identified in their personalization strategies, as we will see in Section 2.

Personalization strategies for the items recommendation are shown in fig.2

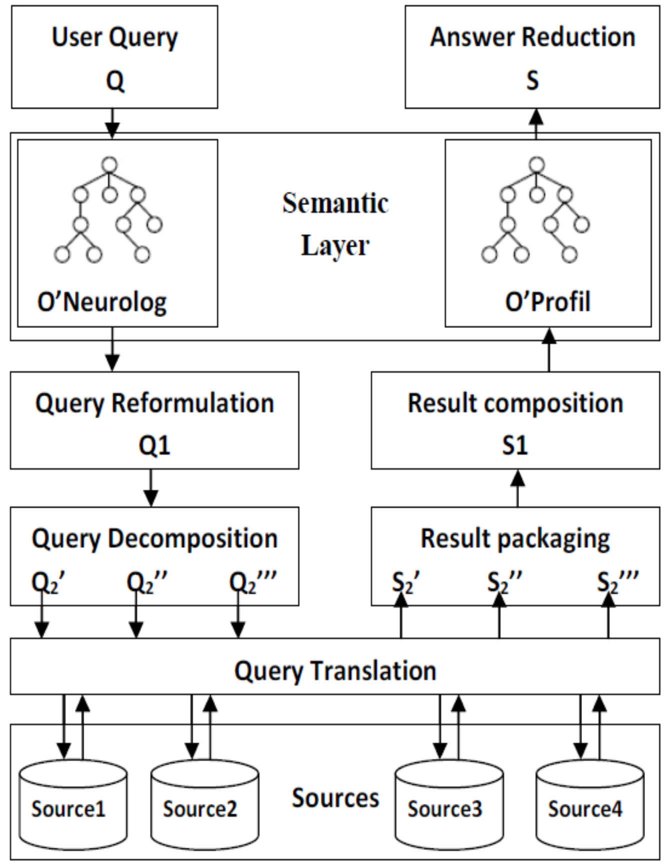

Figure 2. Answering mecanisms

3. Vision of the symantic web and neuro-science

3.1 Neuroscience

Neuroscience is in need of a new informatics framework that enables semantic integration of diverse data sources [6]. Experimental data is collected across different scales, from cell to tissue to organ, using a wide variety of experimental procedures taken from diverse disciplines. Unfortunately the information systems holding these data do not link related data among them, preventing effective research that could combine the data to achieve new insights. Integrative neuroscience research is key to providing a better understanding of many neurological diseases such as Alzheimer's disease and Parkinson's disease, and could potentially lead to a better prevention, diagnosis and treatment of such diseases.

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The field of computer consultation has passed through three historical phases. In the first, attempts were made to improve on human diagnostic performance by rejecting the methods used by clinicians and substituting various statistical techniques [7]. Statistical methods proved to be accurate for small diagnostic domains, but impractical for application to realworld problems [8]. In the second phase, it was recognized that human problem solving methods were deceptively powerful [9] and attempts were made to capture diagnostic logics as fixed decision protocols [10]. Although these met with success in some areas, it was recognized that such protocols suffered from inflexibility [11]. At present, efforts are directed towards building systems which incorporate expert problem solving strategies, but which retain flexibility - 'artificial intelligence' systems [12].

Neurology is a medical specialty concerned with the diagnosis and treatment of all categories of disease involving the central, peripheral, and autonomic nervous systems, including their coverings, blood vessels, and all effector tissue, such as muscle. [13]

Neurological disorders are disorders that can affect the central nervous system (brain and spinal cord), the peripheral nervous system, or the autonomic nervous system.

Conditions can include but are not limited to:

- Brain injury, spinal cord and peripheral nerves
- Cerebral palsy
- Cerebrovascular disease, such as transient ischemic attack and stroke.
- Epilepsy
- Headache disorders such as migraine, cluster headache and tension headache.
- Infections of the brain (encephalitis), brain meninges (meningitis), spinal cord (myelitis)
- …

3.2 Semantic web

The Semantic Web, a maturing set of technologies and standards backed by the World Wide Web consortium [14], offers technical guidance specifically in the area of aggregating and integrating diverse information resources. These Semantic Web technologies can be used to integrate neuroscience knowledge and to make such integrated knowledge more easily accessible to researchers. The foundational technologies of the Semantic Web –Resource Description Framework (RDF [15]), Web Ontology Language (OWL [16]), the SPARQL Protocol and RDF Query Language (SPARQL) – are widely implemented and are backed by a large community of users and developers. The chief advantages of Semantic Web technologies include (1) the widely supported standards backed by the World Wide Web consortium, (2) the ability to make use of the well-established inference mechanisms of description logics, and (3) the availability of a wide range of software tools.

3.3 Ontology

Ontologies are defined as ''formal, explicit specifications of a shared conceptualization'' [17], encode machine-interpretable descriptions of the concepts and the relations in a domain using abstractions as class, role or instance, which are qualified using logical axioms. Properties and semantics of ontology constructs are determined by Description Logics (DLs) [18], a family of logics for representing structured knowledge which have proved to be very useful as ontology languages.

Ontologies have become the cornerstone in the Semantic Web due to two reasons. On the one hand, as these conceptualizations represent formally a specific domain, they enable inference processes to discover new knowledge from the formalized information.

On the other hand, ontologies facilitate automated knowledge sharing, by allowing easy reuse between users and software agents. The last feature was first promoted by standards like RDF [19] and RDFS [20], which added a formal semantics to the purely syntactic specifications provided in XML. Next, DAML (DAML: The DARPA Agent Markup Language, 2000) and OIL [21] arose, which have been finally fused and standardized by W3C as OWL [22]. Nowadays, OWL is the most expressive language in which three sublevels have been defined (Lite, DL and Full). In this regard, the language used to implement the ontology required in our reasoning approach depends on the knowledge and expressive necessities of each application domain and each recommender system.

4. Answering mechanisms from mobile devices

4.1 Formalizing domain knowledge and modeling user preferences

In the field of Semantic Web, an ontology is a formal specification of a conceptualization [23], that is, an abstract and simplified view of the world that we wish to represent, described in a language that is equipped with a formal semantics.

An ontology characterizes that semantics in terms of concepts and their relationships, represented by classes and properties, respectively. Both entities are hierarchically organized in the conceptualization, which is populated by including specific instances of both classes and properties. For example, in the context of a recommender system, instances of classes represent the available items and their attributes, whereas instances of properties link the items and attributes to each other.

In order to reason about the user's preferences, our approach needs a formal representation which includes semantic descriptions of items that have been interesting or unappealing to him/her (named positive and negative preferences, respectively). These descriptions allow the recommender system to learn new knowledge about the user's interests, which will be exploited during the reasoning-based recommendation process.

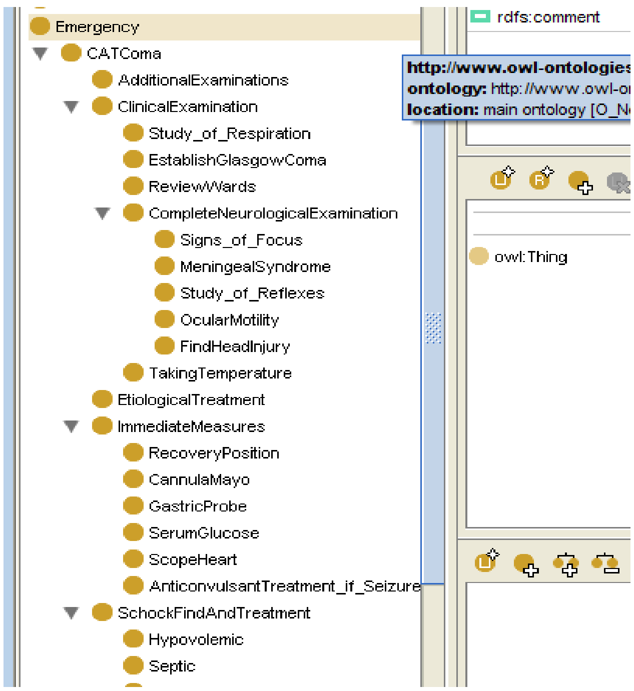


Figure 3. A brief excerpt from an ontology about the Neurology domain.

Our approach models the user's preferences by reusing the knowledge formalized in the domain ontology. As the available items, their attributes and the hierarchical categories are already defined in the conceptualization, our user's models only maintain references to the instances that identify his/her preferences in the ontology.
In previous work [24], we have yield a semantic model to capture the neurological domain knowledge and the user preferences, as :

- Domain knowledge about the neurology sciences, named O'Neurolog
- Profile knowledge grouped by the preferences and needs of the user (patient, Doctor, Lawyer, Banc …), named O'Profile.

All these semantic knowledges are formalized and specified in OWL ontologies with Protégé2000 editor.

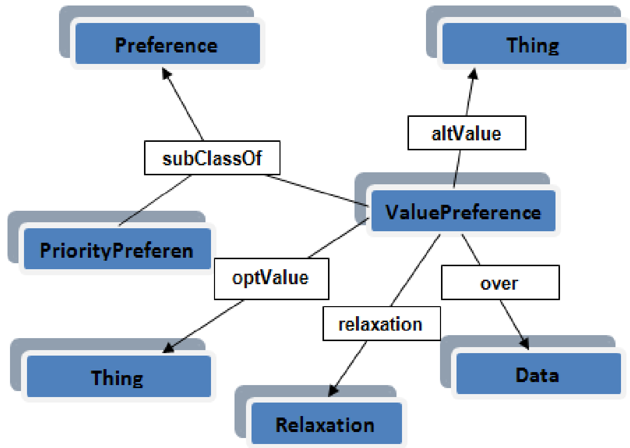


Figure 4. Our ontology-based approach of modeling user in Oprofile.

4.2 Basical principles of mobile answering strategy

In order to fight the aforementioned limitations, our personalization approach defines a metric that compares the user's preferences and the available items in a flexible way: instead of using syntactic techniques, we reason about the semantics of the compared items. For that purpose, we take advantage of the inference mechanisms involving semantic descriptions developed in the Semantic Web. The use of semantic information in recommender systems has been already proposed in various systems. In the simplest proposals, the semantic descriptions serve to provide the users with additional information about the items they have rated.

The approach we propose in this paper fights the limitations of the traditional syntactic strategies by taking advantage of the experience gained in the Semantic Web field. According to the guidelines established by Berners-Lee et al. (2001). Semantic Web is based on describing Web resources by semantic annotations (metadata), formalizing these annotations in ontology, and applying reasoning processes aimed at discovering new knowledge.
Specifically, our approach improves the personalization capabilities of the current recommender systems by resorting to a strategy based on semantic reasoning. For that purpose, we lean on a domain ontology in which the semantic descriptions of the available items (e.g., drugs, diseases . . .) are formalized. Instead of employing the traditional syntactic approaches, our reasoning based strategy discovers semantic relationships between the users' preferences and the items available in the domain

ontology. These relationships provide the system with extra knowledge about the user's interests, thus favoring more accurate personalization processes.

The basical principles of mobile answering mechanisms are:

- Formalize O'profile and O'neurological as knowledge and data Trees: **Abstraction Phase**
- Send user neurological needs as keywords : **Formulation Phase**
- Compute similarity between keyword and O'neurolog Ontology concepts/Properties : **Matching Phase**
- Retrieve from all neurological sources items relevant with concepts/properties more similar : **Collaborative answering Phase**
- Filter and Reduce results according to user preferences, as specified in O'profile : **Pruning Phase**
- Display those results by using Visualization methods according to technical characteristics of mobile devices : **Presentation Phase**

Neurological resources are available on diverse servers as XML Documents according to autonomous, heterogenous, and distributed XML Schemas. Mobile devices are used by users (patients, doctors, medical partners …) in order to access to these data and knowledges. In this context, querying heterogeneous collections of data-centric XML documents requires a combination of database languages and concepts used in information retrieval, in particular similarity search and ranking and their adaptation to mobile context.

In order to improve these principles, our current work focus is based on determining the degree of similarity, called **DoS** between a keyword and a Concept or a Property according to terminological, structural and semantical criteria. So we could exploit many researchs done by RI Community in Tree Matching or Complex Object Mapping. In particular, Tree Embedding algorithm could be useful for this kind of problem.

We present here an improvement of this problem, as proposed by T. Schielder in the paper [25].

In fact, User Query could be formalized as a Query Tree. Let us give an example from a Query b expressed in ApproXQL [25] :

```
book[ title/text() = 'XML'  $and$
      author[ firstname/text() = 'Neil' $and$
              lastname/text() = 'Bradley' ]]
```

Figure 5. ApproXQL Query

TheMapping of an approXQL query to a Query Tree could be done as follows :

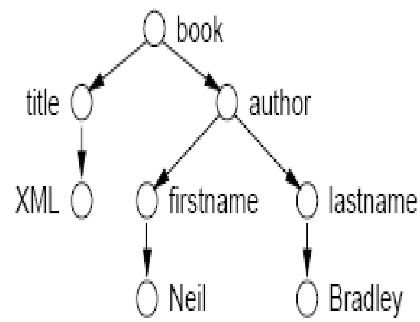


Figure 6. Query Tree.

Authors have shown how to interpret both the data and the query as trees according to several scenarios. With this interpretation, the problem of answering a query can be mapped to the problem of embedding a query tree (User needs) in the data tree (available Neurological resources).

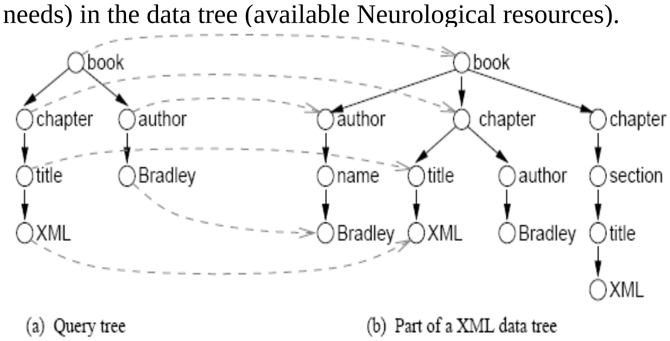


Figure 7. Unordered inclusion of a query tree in a data tree.

The goal is to approximately embed the query tree into the data tree such that the labels and the ancestorship of the nodes are preserved:

Algorithm 1 Retrieving the sorted list of minimal matches of a query tree in a data tree.

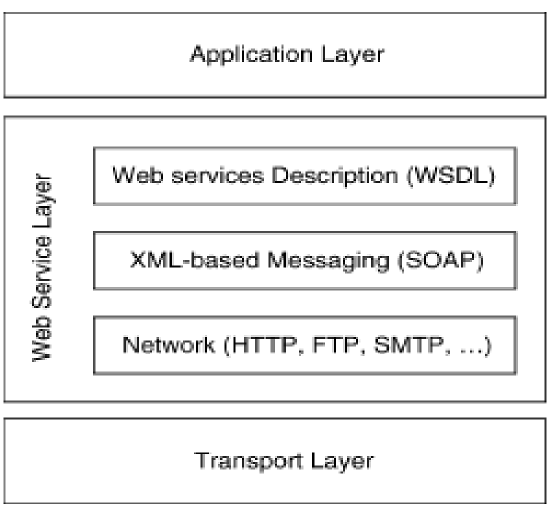
Input: Q — a list of query nodes sorted in postorder
D — a set of data nodes
Output: The sorted list of minimal matches

for all $q_i \in Q$ **do** *// Iterate through the query nodes in postorder*
  $M_{q_i} := \emptyset$ *// The match set belonging to* q_i
  for all $d \in D$ such that label(d) = label(q_i) **do**
    $\mathbb{S} := \{\emptyset\}$ *// The set of proper combinations*
    for all $q_j \in$ children(q_i) **do**
      $\mathbb{S}' := \{\emptyset\}$
      for all $m \in M_{q_j}$ such that d is an ancestor of d_m **do**
        for all $S \in \mathbb{S}$ **do** *// At least,* $\emptyset$ *will be selected*
          if d_m is no ancestor or descendant of any $d_{m'}$ from $m' \in S$ **then**
            $\mathbb{S}' := \mathbb{S}' \cup \{ S \cup \{m\} \}$ *// Append* $\mathbb{S}'$ *by a new partial combination*
          end if
        end for
      end for
      $\mathbb{S} := \mathbb{S}'$
    end for
    if $\mathbb{S} \neq \{\emptyset\}$ **then** *// There is at least one proper combination*
      $M_{q_i} := M_{q_i} \cup \{ \text{select\_minimal\_match}(d, \mathbb{S}) \}$
    end if
  end for
end for
output The match set of the query root sorted by increasing cost

Figure 8. Approximate Tree Embedding Algorithm

5. Realizing a prototype : NeuroService 1.0

5.1 The technical architecture : web services and mobility



Web Service architecture.

A Web service is a software system identified by a URI, whose public interfaces and bindings are defined and described using XML [26]. The definition of a Web service can be exported to a file, published to a lookup service, and discovered by other software systems. These systems may then interact with the Web service in a manner prescribed by its definition, using XML based messages conveyed by Internet protocols.

The Web service architecture defined by the W3C enables application to application communication over the Internet. Web services allow access to software components through standard Web technologies, regardless of platforms, implementation languages, etc.

In term of the Internet reference model, the Web service layer could be placed between the Transport and Application Layer. The Web service layer is based on several standard Internet protocols, whereby the protocols WSDL, SOAP, and typically HTTP as depicted in Fig. 8 should be supported by all Web service implementations for interoperability.

The HTTP protocol that builds the first layer of the interoperable part of the protocol stack is, because of its ubiquity, the de facto transport protocol for Web services. But any other transport protocols such as SMTP, MIME, and FTP for public domains as well as CORBA and Message Queuing protocols for private domains could be used instead.

The XML-based SOAP forms the next layer. SOAP provides XML-based messaging. In combination with HTTP, XML function calls can be sent as payload of HTTP POST. Because of the extensibility of SOAP, one can define customized messages using SOAP headers. The highest interoperable layer is the XML-based Web Services Description Language (WSDL). A WSDL document serves as a contract to be followed by Web service clients. It defines the public interfaces and mechanisms of Web service interactions.

5.2 mobile techcnologies and languages: a state of art

J2ME is a wireless development platform based on Java technology. It is targeted at mobile devices with embedded nature and limited resources. J2ME provides the ability of servers to accept a new set of clients: cell phones, two-way pagers, and palmtops. These devices can be programmed using the Mobile Information Device Profile (MIDP), a set of Java APIs which, together with the CLDC provide a complete Java runtime environment [27]. The main aim behind J2ME is to inherit the powerful features of the Java programming language by designing a light-weight virtual machine (KVM) [28] capable of providing a secure and clean execution environment on resource constrained mobile devices.

The **Android™** platform delivers a complete set of software for mobile devices: an operating system, middleware, and key mobile applications [29].

Windows Mobile and Apple's iPhone provide a richer, simplified development environment for mobile applications.

However, unlike Android, they're built on proprietary operating systems that often prioritize native applications over those created by third parties and restrict communication between applications and native data. Android offers new possibilities for mobile applications by offering an open development environment built on an open source Linux kernel.

As Fig. 9 illustrates, the Open Mobile Alliance (OHA) [30] Google support the Android platform and hope to reach the goal of ensuring global mobile services that operate across devices, geographies, service providers, operators, and networks.

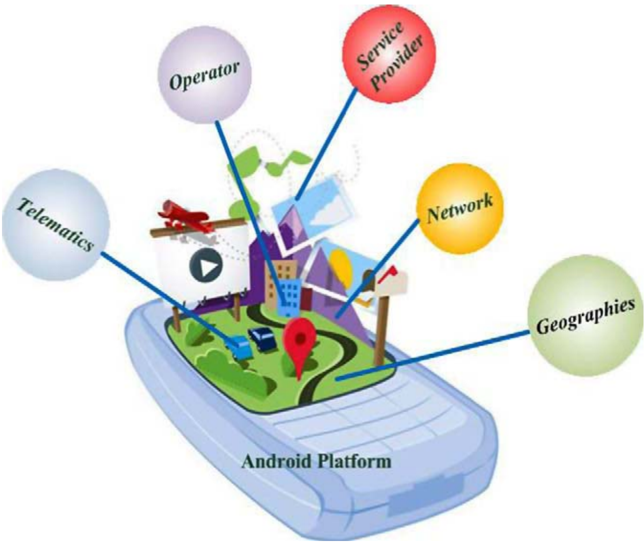


Figure 9. Web Service architecture.

The Android platform has recently been ported into mobile devices, such as notebooks, PDAs, and automotive systems. Android software stack consists of a Linux kernel, a collection of Android libraries, an application framework that manages Android applications in runtime, and native or third-party applications in the application layer.

6. Conclusion and perspectives

In this paper, we have presented a personalization approach that soothes unresolved limitations of traditional syntactic recommendation strategies by applying semantic reasoning techniques. In fact we present principal insights of an approach to find approximate answers to formal user queries. We reduce the problem of answering queries against XML document collections to the well-known unordered tree inclusion problem.

We will extend this problem to an optimization problem by applying a cost model to the embeddings. Thereby we are able to determine how close parts of the XML document match a user query. We present an efficient algorithm that finds all approximate matches and ranks them according to their similarity to the query.

To this aim, we take advantage of the knowledge represented in the domain ontology and the semantic relationships that can be inferred from it. Let us recall that we have capitalized semantic knowledges on neurological domain and user preferences. Further, We shall exploit these semantical knowledges to personalized answers to be returned to users when asking mobile devices.
Instead of offering items with the same attributes as those defined in the user's profile, our reasoning-based approach suggests items semantically related to his/her preferences, thus diversifying the recommendations. These semantic relationships provide additional knowledge about the user's interests and, therefore, favor more accurate personalization processes. Secondly, the collaborative phase of our strategy allows to select a user's neighbors even when the data about their preferences are very sparse.

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