

Ontology Architecture for Semantic Geo Services for Olympia 2008*

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ABSTRACT

For the Olympic Games 2008 in Beijing a prototype platform offering personalized services to support athletes, journalists and spectators is being developed by Fraunhofer ISST in cooperation with the Chinese Institute of Computing Technology (ICT) in Beijing. Geo information and Geo services play an important role here, since most information in this context is geo-related or obtainable using Geo services. Since only relevant information should be delivered to the user, information-logistical and semantic techniques are used in combination. Therefore, a modular ontology has been designed to support semantic queries in this context. It combines different existing or emerging ontology pre-standards and metadata standards: As a basic service ontologie DAML-S is used and combined with an ontology based on ISO19119. Moreover, the mobile use of services may impose validity restrictions concerning location and time. Using semantic techniques a service roaming concept is developed to switch dynamically and transparently between semantically equivalent services, as soon as a validity range is left.

INTRODUCTION

The World Wide Web is currently approaching in two directions, both supporting machine-interoperation: On the one hand there are first Web services used to obtain information or to perform actions, in particular in the Geo domain. On the other hand there are beginnings of a Semantic Web, annotating Web content with machine-interpretable semantic meta information. The latter serves to find what was meant and not what was typed. It complements keyword-based search with context-referred search and logical inference, to deliver only the intended substantial information. These two branches are combined by semantic Web services, whereby e.g. Web services are found due to semantic information or – as an extension – called automatically during inference.

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As an approach to semantic Web services, Fraunhofer ISST in co-operation with the Chinese Institute of Computing Technology (ICT) in Beijing develops a prototype platform providing personalized services to support athletes, journalists and spectators during the Olympic Games 2008 in Beijing.

Service (and information) advertisements and demands are described independently by different user groups (i.e. data/service provider, data/service user), not knowing exactly the needs of each other. The most flexible way to match demands against offers is by using semantic technologies, i.e. ontologies and inference. The objective of the demonstrator is to generate semantic queries from user interactions made using mobile devices. Such a semantic query is answered by using inference based on an appropriate ontology, and results in references to suitable information or services, matching what was meant and not on what was typed.

Naturally, Geo information and Geo services play an important role, since most information is geo-referenced and can be visualized with the help of maps of stadiums or touristic regions. Geo services such as a Geocoder (OpenGIS Consortium 2001) may be used, e.g., to calculate distances between addresses, e.g. to find the nearest shop. Therefore a modular semantic Geo service ontology based on DAML-S (DAML.Org 2003, DAML Service Coalition 2003) and ISO 19119 (ISO/TC 211 2001a) is designed and integrated with different domain ontologies and an ISO 19115-based ontology (ISO/TC 211 2001b).

The paper is structured as follows: First the main ontology concepts and architecture principles are introduced. Then the basis for semantic Geo and other Web services in the Olympia 2008 project is discussed, namely a modular ontology architecture and design, combining different existing or evolving ontologies and meta data standards. Finally, we sketch that the ontology is mainly used for two purposes: for semantic queries and for semantic service roaming.

SOME BASIC CONCEPTS

Ontologies

The original meaning of ontology is the *study of being* as a branch of philosophy. In information science the term *ontology* denotes a knowledge model, which represents a particular domain of interest. There are several definitions for ontology in literature. The most prominent one is: "*Explicit formal specification of a shared conceptualization*" (Borst 1997). This means that the ontology is explicitly defined and there is a formal notation,

interpretable by machines and that the conceptualization is accepted by a group. An ontology consists of the following main constructs:

- **Facts** represent explicit knowledge, consisting of:
 - Classes or concepts are generalizations of instances
 - Properties can be subdivided into scalar *attributes* and non-scalar *relations*
 - Instances represent individual entities and are connected by type-of relation to at least one class; some authors only consider facts about instances as real facts.
- **Axioms** are rules used to add semantics and to infer knowledge from facts. In contrast to facts, they represent implicit knowledge about concepts and relations, e.g., whether a relation is transitive or symmetric.

The facts subset of ontologies with its classes, attributes, relations and instances mainly corresponds to object-oriented data models like UML (OMG 2003) class diagrams. Besides more flexibility in data modeling (e.g. sub-properties, meta-classes), axioms and inference are the most important add-ons of ontologies in comparison to information models. Thus, inference is the main operation defined on ontologies: the axioms are used to derive additional knowledge from facts.

There are several ontology languages as, e.g., compared in (Garshol 2001). DAML+OIL (DAML.Org 2001) is a de-facto standard ontology language, and very near to the coming OWL standard (W3C 2003) developed by W3C. It was selected due to many existing ontologies expressed in this language, but currently has no defined rule language. Since some ontologies require extensive axioms to enable meaningful inference, F(rame)-Logic (Kifer and Lausen 1995, Ontoprise GmbH 2003) was additionally selected in this project. It is a clear, powerful and rich deductive, object-oriented language, combining declarative semantics and expressiveness with rich object-oriented data modeling capabilities.

An Abstract Service Ontology

The first ontology ever was probably developed by *Aristotle* (384-322 BC), who (among many other things) investigated what can be known about anything. His results are described in his work "*Categories*" (Aristotle 350B.C.):

"Expressions which are in no way composite signify substance, quantity, quality, relation, place, time, position, state, action, or affection. To sketch my meaning roughly, examples of substance are 'man' or 'the horse', of quantity, such terms as 'two cubits long' or 'three cubits long', of quality, such attributes as 'white', 'grammatical'. 'Double',

'half', 'greater', fall under the category of relation; 'in the market place', 'in the Lyceum', under that of place; 'yesterday', 'last year', under that of time. 'Lying', 'sitting', are terms indicating position, 'shod', 'armed', state; 'to lance', 'to cauterize', action; 'to be lanced', 'to be cauterized', affection. No one of these terms, in and by itself, involves an affirmation; it is by the combination of such terms that positive or negative statements arise."

In Aristotle's conception these ten categories comprise all the essential qualities that matter and suffice to express anything that may be known about something. In this sense, it is the first upper-level ontology.

These ten categories can be interpreted as ontology dimensions, however, not all are applicable for information and services, e.g., *position* is not meaningful, and *relation* and *quantity* are build into ontology languages (relations and their cardinalities). *Substance* corresponds to content/topic, and together with *time & place* forms the main ontology dimensions. *Quality* is a meaningful dimension. *State* corresponds to context or a precondition of a service. *Action* then is the meaning of a service and *affection* is its effect. A service ontology typically has these additional dimensions, and the ontology DAML-S (DAML.Org 2003, DAML Service Coalition 2003) approximately conforms to this structure.

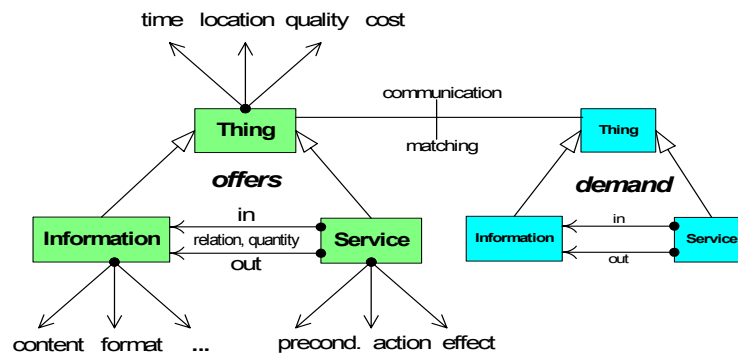


Fig. 1: An Abstract Service Ontology

Additional dimensions not found by Aristotle are e.g., presentation/format and cost, if they are not covered by quality and quantity. All these dimensions are displayed by Fig. 1, using an UML-like notation: here *Service* and *Information* are both *Things* (the top-level class of an ontology), and both inherit the fundamental dimensions of *Thing*. Thus a service itself has dimensions (those of *Thing* and those of *Service*), but all its input parameters (*in*) and its result (*out*) have their dimensions as well (those of *Thing* and

those of *Information*), separately from each other. This stresses the importance of application domain ontologies for a service ontology.

Most of these dimensions correspond to the dimensions of information-logistical systems, concerned with delivering the right information just-in-time, which is a research focus at Fraunhofer ISST (see Fraunhofer ISST 2002).

Thus, these dimension can be seen as a high-level structuring mechanism for ontologies, i.e. for semantic knowledge about information and services. This structuring principle applies both for the definition of service and information *offers*, as well as for actual service or information *demand*, as also depicted by Fig. 1. Between these two sides additional dimensions may span, like communication and matching.

ONTOLOGY DESIGN

In this section we develop the architecture of a concrete service ontology for the application domain, here the 2008 Olympic Games.

Ontology Architecture

The design of ontologies, like software design, is a modular task. The final “product” is composed of different modules, which can be developed and tested independently. An ontology consists of a set of concepts, predicates and axioms, that describe a domain of interest with semantic detail and structure, enabling computers to process its content. According to Guarino (1998), an ontology can be structured into different sub-ontologies as follows and depicted by Fig 2.

- An **upper ontology** is limited to concepts that are meta, generic, abstract and philosophical, addressing a broad range of domains.
- Different **domain ontologies** specify concepts of given domains (e.g., sports, tourism, weather) and are constructed separately.
- The **task ontologies** are similar, they contain knowledge about the usage of the domain ontologies.
- The **application ontology** at the lowest level (in inheritance view) combines and extends the knowledge of all other ontologies.

Project-Specific Architecture

For ontology development the many existing ontologies available in the Web may be considered for reuse as far as possible and may be extended if

necessary. The DAML ontology library (at www.daml.org), e.g., covers more than 200 ontologies (most of them being initial versions), and there are several other libraries with overlapping contents. Several ontologies can be identified at the levels listed above to describe the semantics of Geo services in our application domains, as depicted by Fig. 2:

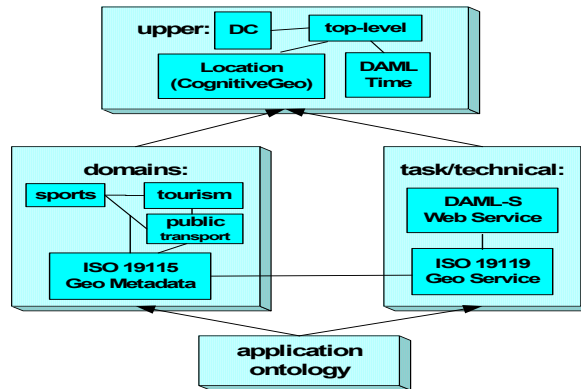


Fig. 2: Ontology Architecture

- **Upper (general) ontologies**, covering the dimensions location, time and content, reusable for different application domains:
 - Location ontology (cognitive Geo ontology): for the *location* dimension in principle a shared ontology for all relevant phenomena on earth is needed. At least it consists of a location subsumption hierarchy, complemented by a geographic feature subsumption ontology.
 - Time ontology: an ontology of temporal concepts for describing temporal content of Web pages and temporal properties of Web services is needed to cover the dimension of *time*. Here we use the pre-standard ontology DAML-Time (Ferguson 2002), influenced by several temporal ontologies developed by different research groups, which also maps to ISO 19108 Temporal Schema (ISO/TC 211 2000).
 - Content ontology: Dublin Core (DC) and especially its refinement Qualified Dublin Core (Kokkelink and Schwänzl 2002) is seen as a simple upper ontology for the *content* dimension, providing access to data and services at document metadata level. The ISO 19115 Core can be mapped to Dublin Core.

- Top-level ontology: **additionally, an ontology of common terms may optionally be useful to connect all ontologies (especially the upper ontologies) to improve query functionality.**
- **Domain ontologies** support different application domains:
 - Sports and tourism ontology: **covers relevant aspects for tourists, journalists and athletes, including, e.g., public transportation, touristic highlights as well as stadium and competition information.**
 - ISO 19115-based ontology: **covers relevant aspects of Geo metadata and enables geo-referencing of all other domain information, e.g., by dynamic feeding of other domain information into maps of the region or the stadiums of interest.**
- **Technical (Task) ontologies:** these task-oriented ontologies are vastly independent of the application domain. For the project context we need to support Web services here:
 - DAML-S ontology: **DAML-S (DAML.Org 2003, DAML Service Coalition 2003) is a pre-standard for a Web service ontology, consisting of three sub-ontologies: a *profile* for advertising and finding services, a *process model* for describing how different service steps cooperate, and a *grounding* supporting service execution by referencing WSDL (W3C 2000).**
 - ISO 19119-based ontology: **adds Geo service semantics to DAML-S and perfectly integrates the ISO 19115-based ontology. It also extends DAML-S meaningfully by providing ISO-oriented subclasses for general DAML-S concepts.**
- **Application ontology:** This ontology serves to integrate all of the above ontologies by adding corresponding relationships.

From a user's point of view, the service ontology is placed above the domain ontologies, since services are used to find, access and modify domain data, and thus deeply depend on domain ontologies. It is important to note that a service ontology needs to be complemented by domain ontologies, since services perform domain-specific tasks and have domain-specific parameters and results.

The ontologies to be developed on each level are based on accepted standards or pre-standards as far as possible, namely ontology and metadata standards. We raised the ISO standards 19115 and 19119 to ontology level to enable inference for Geo objects and services, based on ISO-metadata dynamically imported as ontology instance data. To ease the import, the ISO-based ontologies are quite similar to the metadata models, but connected to the total ontology knowledge as described in the next sections.

Geo Ontology

Approx. 80% of all data can be related to locations, often not explicitly in the form of coordinates, but implicitly in form of addresses or place names. Such geographic features are defined differently in different communities/cultures. The semantics of data is not captured in current Geo metadata, but is crucial for interoperation.

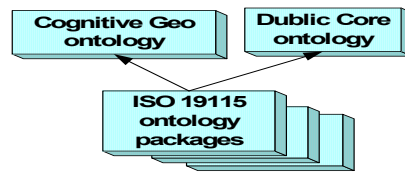


Fig. 3: Simple Geo Ontology Layer Architecture

The Geo ontology is a complex ontology by itself, depicted by Fig. 3. At the highest level we have terms from the non-expert user view (like Dublin Core and cognitive Geo terms), while at the lowest level terms covering standard ISO 19115 meta data are found.

Cognitive Geo Ontology

In principle a *shared ontology for all phenomena on earth* is needed for a Geo ontology, to understand geographic objects and associated cognitive categories. This comprises at least a location subsumption ontology and a feature subsumption ontology.

There are several approaches in literature for this kind of Geo ontology, which cannot be detailed here. We mainly use a cognitive Geo ontology as an upper location ontology, derived from ISO 19115. The skeleton of this ontology can be built by expanding enumeration types of Geo metadata standards into taxonomic class hierarchies, which can then be semantically connected to existing cognitive Geo ontologies.

The ISO standards 19115 and 19119 are specified using UML class diagrams. There are about 25 classes which have a <<CodeList>> or <<enumeration>> stereotype, being types with a finite well-defined set of values. The same holds for several string attributes, like *Language*, *FeatureType* and *Location*. In principle, each of these types can be modeled as a taxonomy to enable subsumption inference, and also additional relations and knowledge can be added then, which would otherwise only be implicit.

The modeling of taxonomy ontologies is discussed in Welty (1998), where the problem of inconsistencies between representing subjects as concepts or

as instances is explained and alternatives of modeling are presented to avoid the instance/class conflict (for hierarchical modeling the class is needed and for assigning a taxonomy value the object is needed). However, modern inference machines like Ontobroker (www.ontoprise.de) and XSB (xsb.sourceforge.net) can deal with attributes having classes as their values. We thus refer to taxonomies directly.

Not all of these taxonomies belong to the cognitive Geo ontology, however, the most important ones which do are feature types and locations, and they form the skeleton of the cognitive Geo ontology.

The feature types are a set of terms for categories of geographic places and terms to indicate the nature of a place. Here, e.g., the well-known Alexandria Digital Library Feature Type Thesaurus/Taxonomy (<http://www.alexandria.ucsb.edu>) can be used. When a corresponding *Gazetteer* service (OpenGIS Consortium) is available, such a feature type hierarchy may in principle be imported using operation *GetFeatureType*.

As a simple location hierarchy we consider the well-known GeoWeb taxonomy, which is used in Microsoft's UDDI (UDDI.Org 2002) implementation. It is a hierarchy of levels world-continent-state-country-city. However, this is no taxonomy in terms of an inheritance hierarchy, but more a partonomy, since all of them are locations, but e.g., a city is not a special country, but part of a country. Thus our Geo location ontology defines *Continent*, *State*, *Country*, *City* all as sub-concepts of *Location*, which inherits attributes like *name* and *code* and the single-valued transitive relation named *in*, denoting enclosed locations. When a corresponding *Gazetteer* service (OpenGIS Consortium 2002) is available, such a location hierarchy including its *in*-relationships may in principle be imported using operation *GetFeature*. This is meaningful due to the amount of location data on lower levels.

ISO 19115-based Ontology

The ISO 19115 provides a schema for describing digital geographic datasets using a comprehensive set of more than 400 mandatory or conditional attributes, structures in different packages which are modeled using UML. These attributes support data discovery (by general information about data and metadata), checking for fitness (quality, spatial and temporal extent), data access (size, format, price, restrictions) and data usage. The metadata elements are organized in a hierarchical structure, specified in using UML packages. This metadata model can be translated to an ontology in a straight-forward way. We restricted ourselves to a subset of about 200 attributes, leaving out those which are typically not used.

Some Geo data servers able to provide ISO 19115-conformant metadata for different kinds of Geo objects of regions being of interest for a given scenario can be used to provide facts about Geo objects. This Geo meta data is the instance data of the ISO 19115-based ontology and extends it to a Geo knowledge base. Since a redundant storage of meta data (in a GIS system and in a semantic registry) is to be avoided, ontology data at instance level should be imported only when necessary.

Mapping ISO 19115 to Dublin Core

Dublin Core (DC, <http://www.dublincore.org>) is an interoperable metadata standard to describe resources. The ISO 19115 Core can roughly be mapped to DC's 15 attributes, and thus provides Geo-data retrieval at document level, i.e. at the content dimension.

For DC there are already RDF ontologies. In a DC ontology each element maps to an RDF property and some DC elements are direct sub-properties of RDF language elements (e.g. *dc:title* -> *rdfs:label*, *dc:relation* -> *rdfs:isDefinedBy*). This is inheritance on attributes, a feature of most ontology languages. The DC mapping extends this approach, declaring the ISO 19115 Core elements as sub-properties of dc-elements. There is an improvement to this approach by using a refinement of Dublin Core, i.e., Qualified Dublin Core (Kokkelink and Schwänzl 2002). This adds refinements and encoding schemas to Dublin Core elements. E.g., *dc:date* has sub-properties *qdc:created*, *qdc:modified*, etc. and encoding schemas *DCMI period* and *W3C-DTF* (i.e., limits of time interval, and time point). For *dc:coverage* there are sub-properties *qdc:spatial* and *qdc:temporal*.

Service Ontology

The objective of this ontology is to cover semantic Web services, with a focus on Geo Web services. Different domain ontologies shall be plug-able to this ontology to cover different application scenarios. Moreover, services should be classifiable and searched along dimensions like time, location, content, quality, presentation, cost, etc.

DAML-S

The DAML-based Web Service Ontology (DAML-S) is the DAML-ontology for Web services and provides a domain-independent core ontology for a computer-interpretable description of properties and capabilities of Web Services (DAML.Org 2003, DAML Service Coalition 2003). It is developed by a research group at DARPA, but accepted by DAML.Org and expected to be standardized by W3C in the context of OWL. Thus DAML-

S should be used if possible, at least a subset of DAML-S should form the core of our service ontology. It consists of three main sub-ontologies:

- **Service Profile:** a high-level description of the service provider and the functionality of the Web service. It consists of an actor description (service provider or user), a functional description (inputs, outputs, preconditions, effects) and functional attributes (like quality rating, geographic radius, etc.). Thus it supports promotion and finding of services similar to UDDI (UDDI.Org 2002), but semantically using inference.
- **Service (Process) Model:** a workflow description defining how the service works, when composed of several steps. It is an alternative approach to languages such as BPEL4WS (IBM developerWorks 2002).
- **Service Grounding:** describes the kind of information exchanged with the service and thereby supports service execution. It is highly interrelated to WSDL (W3C 2000) and normally used together with WSDL.

ISO 19119 Geo Service Standard

The ISO 19119 Standard for Geo Services (ISO/TC 211 2001a) provides a framework to develop services that enable users to access and process geographic data from a variety of sources within an open information technology environment and supports geographic interoperability.

The abstract service model is the basis for the service metadata schema defined in ISO 19119 using UML diagrams, which can be transformed to a ISO 19119-compatible service ontology in a straight forward way. Moreover a Geo service taxonomy defines classes of services based on the semantic type of computation that they provide, namely Human interaction services, Model/Information management services, Workflow/Task services, Processing services, Communication services and System management services, and refines this taxonomy with a detailed Geographic services taxonomy.

Combining DAML-S and ISO 19119-based Ontologies

DAML-S has been developed with extensibility in mind, since some concepts like *QualityRating* only exist as an example in DAML-S, and some relations (such as service input/output parameters) have range *Thing*, i.e., may have values from arbitrary domain ontologies.

Our focus is on the Service Profile, since the profile is used to advertise and find services. We refined it by the ISO 19119-based ontology for Geo Web services, which is very similar to some extent, but goes into more detail concerning Geo-related aspects of services, especially by a natural linking to the ISO 19115-based ontology already integrated to the ISO 19119-

based ontology. This subclassing and extension of DAML-S concepts supports Geo services and is partly useful for other services as well.

E.g., for *GeographicRegion* we use our location hierarchy ontology based on GeoWeb and other concepts from ISO 19115, like *EX_GeographicExtent*. Moreover, we added a concept *ServiceTimes* with sub-concept *MD_MaintenanceInformation*. and our Geo service taxonomy (*ServiceTypes*) as an additional *ServiceCategory*, for *QualityRating* *DQ_DataQuality* was used, and a branch *ServiceConstraints* was added, consisting of concepts *MD_Constraints* (with its sub-classes) and *ServiceCosts*.

Moreover, some similar concepts can be identified, either on concept level or at least on property level. E.g., *Actor* and *SV_ServiceProvider* together with *CI_ResponsibleParty*, *Parameter* and *SV_Parameter*, *Profile* and *SV_ServiceIdentification*. Their semantic overlap has to be identified.

ONTOLOGY USAGE

The service ontology is mainly used for answering semantic queries and forms the basis for automatic semantic service roaming.

Semantic Queries

The main benefits of a semantic search in contrast to a keyword search are *to find what was meant, not only what was expressed*. This means that

- alternative search terms may be considered (e.g. synonyms, languages),
- the context of a term can be given (e.g. to treat homonyms and to distinguish subject, predicate and object roles of terms),
- semantic terms can be logically combined,
- the total knowledge of facts and axioms/rules of the ontology can be applied, using inference as the main operation on ontologies to combine all these aspects.

The main purpose of ontologies is to infer additional knowledge from facts and rules, driven by a corresponding query. This mechanism is used to make the matching of different offers with the current demand more flexible, i.e. to match what was meant and not what was expressed.

During this semantic matching, Geo (and other) services may be called, either to import additional metadata to the ontology on-the-fly, or to perform complex calculations. An example for the latter is to call a *Geocoder* ser-

vice (OpenGIS Consortium 2001) parameterized by a logical location name to obtain its coordinates and to calculate distances between points based on coordinates or even roads on a map. Some inference engines allow for plug-in of new predicates which can then be used during inference, which is required here.

How will a user formulate a semantic query using his mobile device? We cannot expect him to know a complex query language or the ontologies used. Among others, the following approaches exist:

- Provide predefined standard queries, which can be executed by a click. Perhaps an additional keyword can be entered as well.
- Provide a query wizard to generate the query dynamically.
- Provide concept and property selection by ontology navigation.
- Enable queries using the query language of the inference engine (F-Logic (Kifer and Lausen 1995, Ontoprise GmbH 2003) in our case), but only for expert users.
- Provide free natural language queries. But since no complete text mining approach will be used for the first prototypes, the input can be parsed along all known terms of the ontology (concepts, relations, object names and their aliases and translations). It may be required for a first prototype to enter subject predicate object in this order, which are then transformed to “*subject [predicate->>object]*” F-Logic molecules. Special keywords like *and/or/not* may be used to combine those molecules, and keywords like *where, when, how, here, today*, etc. and their language variants may be treated specially, e.g. to predefined time and location filtering predicates.
- Combine some or all of these approaches.

Using a profile editor the user may enter personal data and preferences. This information may be stored on smart cards and is transformed to ontology instance data used for the semantic query. Profile information may be additionally combined with *context* information determined by sensors, e.g. for the current location. This also enables push services, i.e. semantic queries performed by the system, delivering relevant information to users, based on their profile and actual context.

Semantic Service Roaming

Using semantic service descriptions not only supports a better retrieval of resources. It can be used for various automated tasks. Especially in mobile applications users are typically changing their locations. If they have the

need for a specific location-based service type at different locations, they have to use either a global service, or they have to change between regional services every time they move from one region to another.

For service providers it is usually easier to concentrate on offering a specific location-based service for a limited area, e.g. a city or a county. Services like restaurant finders or event guides depend on certain knowledge about restaurants or events in a specific area. The more limited a covered area of a service is, the more easy it is for a service provider to get that knowledge. Thus we have to support distributed, spatially limited services in mobile service platforms. An aggregation of several distributed services is consequently supposed to lead to a more or less global coverage.

From a user's point of view a switch between services due to changing his position should happen transparently. The service platform therefore has to track the user's position and automatically connect to the relevant services.

For performing such a service roaming, service descriptions have to include some information about service validity, e.g. the covered area, being part of the service semantics. When the user sends a service request to the service platform, the platform has to add the user's position as a parameter for service retrieval. This ensures that only services being valid for the user's actual position can be chosen. Although location is the most obvious example for a service validity restriction, many other context dimensions can be regarded, such as time, weather, or bandwidth, just to name a few.

If a user accesses a spatially limited service over a longer time period while moving, e.g. a traffic service, then it is not sufficient to initially search for an appropriate service covering the user's actual position. In fact the service platform has to align the user's position and the service's validity area permanently as long as the service is used. As soon as the user leaves the validity area, the service platform has to find another appropriate service immediately, capable to perform an equivalent task.

Generally, from our point of view, users are not limited to use one service at a time for a specific task. Especially when it comes to information services the result can also be aggregated from different, semantically equivalent information services. In this case the platform has to decide for each service request which are the relevant and valid services to be used. Assuming that there are no fixed service types, the problem here is to decide whether two services are equivalent enough or not. Therefore it is necessary to infer the equivalence or "logical distance" between two services to be able to retrieve best matches.

SUMMARY

The objective of this document was to develop ontologies for semantic Web services, with a focus on Geo Web services and a scenario-driven application domain, namely the 2008 Olympic Games. We have achieved this by combining different standard, e.g. ontology pre-standards like DAML-S and DAML-Time, and metadata standards like qualified Dublin Core and ISO 19115 and 19119, which we raised to the ontology layer. A basic cognitive Geo ontology was constructed by blowing-up enumeration types of metadata standards.

Moreover, we integrated existing ontologies with new ones where some overlaps were identified, namely between DAML-S and ISO 19119 on the one hand, and qualified Dublin Core and ISO 19115 on the other hand. Hereby, DAML-S, seen as the primary service ontology, benefits from different additions and refinements towards an ISO 19119-based ontology.

The combined ontology is open to the plug-in of new domain sub-ontologies to support new application and different scenarios, and by adding. For the Olympic Games we support domains like sports, tourism, public transport and weather. Moreover, we focus on Geo data and services, since each of these domains needs underlying maps, e.g. of interesting touristic regions or of sports stadiums for information to be displayed in a modern and user-friendly way. To support the mobile use of services, a roaming concept was sketched.

By this research, we started to combine four actual research domains, namely Semantic Web & ontologies, Web services & registries, Geo information systems & Geo services, and Information Logistics. The next steps are to improve and fully integrate all sub-ontologies developed, either by using additional relations, or by using rules and axioms. Moreover, we need to instantiate the schema with facts about features and locations and with sample semantic service descriptions, and we will develop use cases and sample semantic queries against registered services.

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