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Jun Shen

University of Wollongong, jshen@uow.edu.au

Aneesh Krishna

University of Wollongong, aneesh@uow.edu.au

Shuai Yuan

University of Wollongong, sy242@uow.edu.au

Ke Cai

University of Wollongong

Yuemin Qin

University of Wollongong

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Keywords

pragmatic, GIS, oriented, ontology, for, location, based, services

Disciplines

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A Pragmatic GIS-Oriented Ontology for Location Based Services

Jun Shen¹, Aneesh Krishna², Shuai Yuan¹, Ke Cai¹, Yuemin Qin¹

1-Centre for Information Systems and Technology Research

School of Information Systems and Technology

2-Decision Systems Laboratory

School of Computer Science and Software Engineering

Faculty of Informatics, University of Wollongong

Wollongong, NSW, 2522, Australia

{jshen, aneesh}@uow.edu.au, {shuai.yuan, jkate_cai, yueminqin}@hotmail.com

Abstract

With advances in automatic position sensing and wireless connectivity, location-based services (LBS) are rapidly developing, particularly in fields of geographic, tourism and logistic information systems. Currently, Web service has been viewed as one of most significant innovations in business industry, and designed on demand to provide spatial related information for LBS consumption. However, the traditional Web Service Description Language (WSDL) cannot meet those requirements, as WSDL is not able to support semantic content and information. In recent years, Ontology came up with an effective approach to enhance service description, automated discovery, dynamic composition, enactment, and other tasks such as managing and using service-based systems. In this paper, we propose geographic ontology based on Geography Markup Language (GML) and extend OWL-S profile to form geographic profile. Web service, which is advertised on the basis of our GeoProfile, contains geographic information inherently.

1. Introduction

With the soaring usage of Internet, communication technologies and virtually seamless network, the emerging e-commerce has gradually changed people's lifestyles to a fashionable and facilitated mode from e-shopping to e-hiking. As a branch of m-commerce (Mobile Commerce), Location-Based Services (LBS) has attracted more attention against its historical imperceptibility due to its inherent dynamism and unpredictability [14]. With regard to mobile devices, LBS adapts to a user's location and situation. For instance, an important advantage of LBS is that users do not have to enter zip code or other location identifiers to mobile devices or applications [9]. Typical

applications of LBS can be found in military dispatch and cooperation, assets tracking, business logistics, transportation and personal positioning systems. On the other side, increasingly popular Web services technologies have brought enormous advantages to people, such as software and system's reusability, scalability, integration and automation. WSDL (Web Service Description Language) being the main Web service description language has become imperative part of Web services and been widely applied in Web services nowadays. Furthermore, mobile services and wireless applications have gained more attention in the e-service applications. Naturally, the application of Web services under LBS environment is a great success for online business and individual applications, since it owns both benefits of business process automation, integration, scalability and location-oriented real time and convenient assistance [6].

However, the current information used in LBS-related Web services for matching and searching is mainly based on the syntax rather than semantics, and WSDL has not been equipped with any description functions of semantic Web service [7]. Motivated by this demand, this paper proposes to address this problem to better facilitate the location awareness of Web services in mobile and wireless environment, by adding semantic characteristic for Web service description.

The paper is organised as follows. Section 2 describes the background of related technologies and introduces the directions of our design. In section 3, we mainly discuss the related work and present our structure design of geographic ontology. Then in section 4 we extend OWL-S profile with geographic features to suit LBS requirements, such as non-functional aspects, and provide an example of geographic profile in OWL. Section 5 describes the usage and principle of our approach for real application. Finally, section 6 concludes current work

and indicates further research.

2. Background and Design Philosophy

2.1 OWL - Web Ontology Language

Ontology is used to capture knowledge about some domain of interest. It describes not only concepts within a domain but also relationships which exist between those concepts. In computer science, ontology is a data model that represents a domain and is used to reason about the objects in that domain and the relations between one another. It describes individuals, classes, attributes and relationships. One typical usage of ontology is semantic Web, which focuses on uploading documents with machine interpretable meaning on the Web. Web Ontology Language (OWL) is the recommended ontology language from the World Wide Web Consortium (W3C)*. This paper employs OWL to design geographical ontology, since it is used to facilitate LBS locations. There are three kinds' sub-languages of OWL ontology: OWL-Lite, OWL-DL and OWL-Full. OWL-Lite is the least expressive sub-language, while OWL-Full is the most expressive one [5]. OWL-DL is chosen in this paper, since it is the compromise between simplicity and expressiveness.

There are two modeling methods with OWL-DL in LBS Web services: modeling with concepts and modeling with individuals. We shall be using the modeling with concepts notion: input/output of an operation is characterized by atomic concept conditions, each pointing to specific concepts in the ontology.

2.2 GML-based Geographic Ontologies

A widely accepted ontology that models physical objects and their location is the Geography Markup Language (GML), standardized by the OpenGIS Consortium and used in the Geographic Information System (GIS) community [8]. GML is the XML grammar defined by the Open Geospatial Consortium (OGC) to express geographical features. GML serves as a modeling language for geographic systems as well as an open interchange format for geographic transactions on the Internet. Building geography ontology upon GML can overcome organizational and legal barriers to the use of geographic information and improve the existence and availability of geographic content [13]. Therefore, GML is followed in building geographic ontology in our project.

Basically, GML provides a variety of objects for

describing geography including features, coordinate reference systems, geometry, topology, time, units of measure and generalized values. However, GML is built on the XML data model and the XML Schema type system. It needs to be transferred into OWL to express typing information.

2.3 Design Principles

Based on the two main specifications (GML and OWL introduced above), our work has two steps according to Elenius's design philosophy [3]. The first one is to define geographic ontology in terms of OWL classes, properties, and instances based on GML. The second step is to create an OWL-S description of the service, extend ServiceProfile (the most important part in semantic description of Web services in OWL-S), which then be related to the domain (geography) ontology which have been created in step one.

3. Related work and Geographic Ontology

Many research groups have been involved in building geographic ontologies. In the past, three geographic ontologies have been proposed: 1) Kaoru Hiramatsu and Femke Reitsma's ontology system [4]; 2) Geographic Resource Description Framework (GRDF) from Bhavani Thuraisingham's group [1]; 3) OpenGIS Consortium-Geographical Markup Language (OGC-GML) [2].

The three main geographic ontologies have been critically analysed and compared in our research. The last one, OGC-GML ontology, has been validated by OWL DL validator and could cover the most concrete geographic information; hence it has been deployed (and adopted) by our project as basic ontology for describing further OWL Web service description.

3.1 Kaoru Hiramatsu and Femke Reitsma's Ontology System

As the work presented in [4], authors have built three major ontologies: *geoFeatures.owl*, *geoCoordinateSystems.owl* and *geoRelations.owl*, to describe geographic ontologies. The *geoFeatures.owl* expresses a base set of geographic features such as countries and cities. It functions as a base set of overall geographical description in two sub areas: *SpatialThing* and *SpatialDescription*. The latter describes the geographical shapes in terms of geometry while the former describes a complete set of geographic features according to details of real life information of a place, such as Capital City, Division, State, Post Code etc. The *geoRelations.owl* is based on *geoFeature.owl* since the accurate semantic is the

* W3C. OWL Web Ontology Language Guide.
<http://www.w3.org/TR/2004/REC-owl-guide-20040210>

premises of their relationships. GeoFeature.owl describes the geographical relationships of places in three directions, Cardinal Directions, Spatial Rerectations and Units. In our LBS Web service OWL descriptions, the first two are more important since the directions and the distances of two objects are more often used in describing the accurate positions of two relative objects in the real life. The *geoCoordinateSystem.owl* is based on SpatialThing and SpatialDescription and Point of GeoFesture.owl and has the CoordinateOrigin defining the coordinate origin for a local coordinate system. There are two coordinate systems defined in Coordinate System: Local Coordinate System and Geographic Coordinate System. The former defines class of coordinate systems that are locally defined or relative to some specific place or object. The later defines the class of geographic coordinate system using latitude and longitude to define the locations of points on the surface of the earth. These two coordinate systems are the main systems to be used in LBS Web service descriptions.

This geographic ontology system is quite complete, however, as the authors admit, they did not follow any standards or specifications.

3.2 Geographic Resource Description Framework (GRDF)

GRDF is an OWL-DL profile of GML 3.1.1 [1]. Its intended users are cross-domain application developers, semantic Web services developers and data-mining agents. RootGRDFObject is the parent of RingTypes, GeomertyOrRing, GeometryTypes and Fragments. GRDF also defines five types of GeomertyTypes, they are CompositeTypes, _0DimGeomertyObject, _1DimGeomertyObject, _2DimGeomertyObject and AggregateTypes.

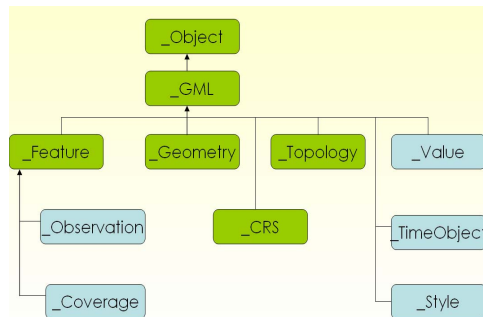


Figure 1: GRDF Object Hierarchy [1]

However, the content organization of GRDF is different from GML; it is more intuitive for non-geospatial experts. In figure 1, it describes the relationship between GRDF and GML. Objects in blue (light gray) color are not covered in GRDF.

3.3 OGC-GML

The authors in [2] had done the work of building an ontology for geographic information based on GML 3.0. Their ogc-gml.owl ontology has been validated as OWL DL. Compared with the other two systems, this geographic ontology system is the most complete one to use. To avoid reinventing the wheel, we employ this ontology to describe geographic information for Web services. In the wide range of geographic objects, gml:Geometry is attracting much attention. The position of a Web service description in the coordination system is easy for LBS to use. In GML, the geometric characteristics are described by a property of the object, which is a relationship between the object and some geometric object. Point, Solid, Surface and Curve are defined as Geometric primitive type to describe geometric characteristics [15]. To simplify things, we only use Point to indicate coordinate information for a Web Service. A point has “coordinates” that determine its location relative to some coordinate system (e.g. (latitude, longitude)). The hierarchy of class Point is shown in Figure 2.

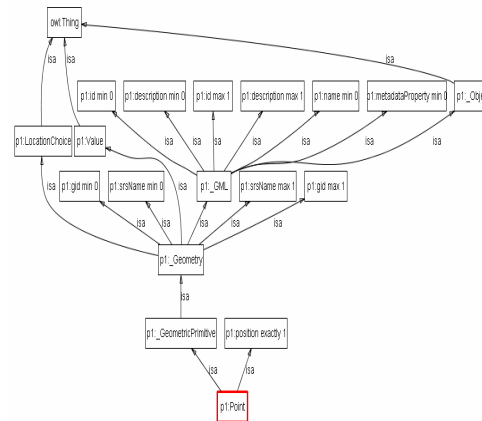


Figure 2: “Point” Hierarchy [15]

OWL Definition of ‘Point’

Based on OGC-GML ontology, the OWL definition of Point is listed in the following:

```
<owl:Class rdf:ID="Point">
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty>
        <owl:ObjectProperty
          rdf:ID="position"/>
        </owl:onProperty>
        <owl:cardinality
          rdf:datatype="http://www.w3.org/2001/XMLSchema#int">1</owl:cardinality>
      </owl:Restriction>
    </rdfs:subClassOf>
  </owl:Class>
```

```

<owl:Class
rdf:about="#_GeometricPrimitive"/>
</rdfs:subClassOf>
</owl:Class>

```

In this definition, Point is defined as a subclass of _GeometricPrimitive.

4. Web Service Description Extension with OWL-S

4.1 OWL-S Description

OWL and other ontology languages are encouraging the fast development of a new generation of Web markup languages (at semantics level). OWL-S has been designed to enable automatic Web service discovery under OWL descriptions of Web services, including properties and capabilities. New descriptors could be used to stimulate a registry of services, to provide better indexing and retrieval features for search engines or to provide semantic information for match-making system. Following three essential types of Web service knowledge are provided by three components of OWL-S*: The *service profile* advises what the service does. It includes a description of what is accomplished by the service, limitations on service applicability and quality of service, and requirements that the service requester must satisfy to use the service successfully. The *service model* advises a client how to use the service. It details the semantic content of request, the conditions under which particular outcomes will occur, and where necessary, the step by step processes leading to those outcomes. The *service grounding* advises how to access the service. It includes communication protocol, message formats, and other service-specific details.

In summary, the ServiceProfile provides the information needed for an agent to discover a service, while the ServiceModel and ServiceGrounding provide enough information for an agent to make use of a service, once found. In our LBS based semantic Web service descriptions, ServiceProfile is our focus since the geographical ontologies are involved mainly in this component at the stage of discovery during the whole deployment of Web services.

4.2 Extension on ServiceProfile

As we have discussed before, OWL-S ServiceProfile describes three basic types of information of a service: which organization provides the service, what kinds of function the service computes, and a host of features that specify characteristics of the service. In OWL-S

* OWL-S: Semantic markup for Web services, <http://www.daml.org/services/owl-s/1.1/overview>

specification, the profile allows the description of three types of properties to describe features of the service. The first type of information specifies the category of a given service. The second type of information is quality rating of the service. The last type of information is an unbounded list of service parameters that can contain any type of information. Therefore, to extend ServiceProfile, the last type of property, service parameters, should be extended.

However, in the new OWL-S 1.2 Pre-Release which went public in March 2006, some properties such as serviceParameter, serviceCategory, serviceClassification, and serviceProduct have been deprecated. In this specification, we are encouraged to create a new ontology that contains a subclass of Profile (and imports Profile.owl), and declares the additional needed properties with the subclass as their domain. In this project, we extend Profile.owl; then add an ObjectProperty link to the geographic ontology we built before. Then the geographic information can be stored in the ObjectProperty location. Every Web service, which wants to include geographic information, can be enhanced by our approach.

4.3 Facilitation of Incorporating Non-Functional Requirements

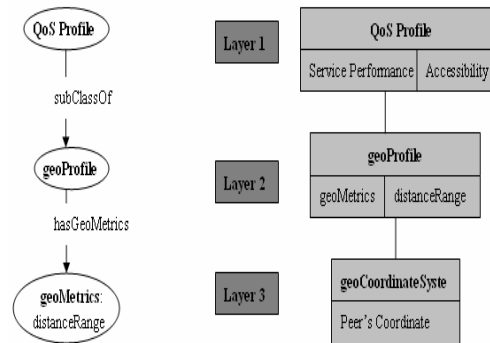


Figure 3: Data type property and high-level structure in Geo profile

In general, non-functional requirements of LBS include qualities and constraints [17], which are an essential aspect in providing users better services. Qualities are properties or characteristics of the service that its requestors care about and hence will affect their degree of satisfaction with the service, such as the availability and accessibility of services [16]. Normally constraints, unlike qualities, are not subject to negotiation and are theoretically restraining the trade-off in the optimisation of service design and deployment. For example, distance constraint is usually viewed as an important and basic concept when searching for the best suitable service. Therefore, making reasonable use of ontology's capability to describe services' qualities

and constraints will have much significance and benefits for providing better LBS.

Figure 3 indicates the relationships between QoS profile and Geo profile, and the logic in using geographic features for describing services' non-functional features. The coordinate (either two-dimension or three-dimension) can be generated from a geographic coordinate system, and it is easy to calculate the distances between service requestor and service provider. For example, the user would be able to find and select the nearest service effectively when hesitating to make decision.

Metrics definition about "DistanceRange":

```
<owl:Restriction>
  <owl:onProperty
    rdf:resource="http://localhost:8080/
    GeoMetrics.owl# DistanceRange"/>
    <owl:maxCardinality
      rdf:datatype="http://www.w3.org/2
      001/XMLSchema#nonNegativeInteger"
      >100</owl:maxCardinality>
</owl:Restriction>
```

As we mentioned above, the metric of "DistanceRange" is viewed as a basic constraint when selecting most appropriate LBS for a service requestor and it can be set according to different service requirements so as to enhance the service accessibility. It is feasible to establish a better link between a potential service or a partially composed service, and an expected or requested set of location requirements. We are also able to use this approach to rule out noisy or less viable options.

4.4 GeoProfile.owl Hierarchy

In this part, we present the GeoProfile.owl file by separating it into three parts, Namespaces, Ontology Headers and Elements.

Namespaces:

Most of the namespaces are directly from OWL-S specification. However, ogc-gml namespace is declared for employment in describing the geographic information.

```
<!ENTITY ogc-gml
http://loki.cae.drexel.edu/~wbs/ontolog
y/2004/09/ogc-gml >
```

Ontology Headers:

This area includes ontology version information and some comment about this ontology. Since GeoProfile.owl is derived from OWL-S Profile, service and process should be imported. In addition, ogc-gml is also needed to be imported for further use.

```
<!-- Ontology Headers:-->
<!-- version information and comment -->
<owl:Ontology rdf:about="">
  <owl:versionInfo>
```

```
$Id: GeoProfile.owl,v 1.0,
21/03/2007$
</owl:versionInfo>
<rdf:comment>
  OWL-S Profile extension with
  geographic information. Version March/07
</rdf:comment>
<!-- Import other ontology -->
<owl:imports>
  <owl:Ontology rdf:about="&service;"
/>
  </owl:imports>
  <owl:imports>
    <owl:Ontology rdf:about="&process;"
  />
  </owl:imports>
  <owl:imports>
    <owl:Ontology rdf:about="&ogc-gml;"
  />
  </owl:imports>
</owl:Ontology>
```

Elements:

This part is the core of our GeoProfile. At first, we name our ontology as GeoProfile. Then OWL-S Profile is declared as GeoProfile's parent. According to OWL specification, all the properties in OWL Profile are inherited by GeoProfile.

```
<owl:Class rdf:ID="GeoProfile">
  <rdfs:label> GeoProfile </rdfs:label>
  <rdfs:subClassOf
    rdf:resource="&profile;#Profile" />
  <rdfs:comment>
    Definition of Geographic Profile
  </rdfs:comment>
</owl:Class>
```

At last, we add an Object property which is named location to indicate the geographical information for the advertised Web service. In this property's definition, ogc-gml:Point is employed for geographical description.

```
<!--location property -->
<owl:ObjectProperty rdf:ID="location">
  <rdfs:domain
    rdf:resource="&GeoProfile"/>
  <rdfs:range
    rdf:resource="&ogc-gml;Point"/>
</owl:ObjectProperty>
```

4.5 An Example for OWL-S Geographical Profile

We provide a simple example to demonstrate how to use GeoProfile to describe Web service.

ExampleProfile:

In the namespace declaration part, geoProfile and ogc-gml should be declared first.

```
<?xml version='1.0'
encoding='ISO-8859-1'?>
<!DOCTYPE uridef[ <!ENTITY rdf
"http://www.w3.org/1999/02/22-rdf-synta
x-ns">
```

```

<!ENTITY rdfs
"http://www.w3.org/2000/01/rdf-schema">
<!ENTITY owl
"http://www.w3.org/2002/07/owl">
<!ENTITY xsd
"http://www.w3.org/2001/XMLSchema">
<!ENTITY geoProfile
"http://www.uow.edu.au/GeoProfile.owl">
<!ENTITY ogc-gml
"http://loki.cae.drexel.edu/~wbs/ontology/2004/09/ogc-gml">
<!ENTITY DEFAULT
"http://www.example.com/example.owl">
]>
<rdf:RDF
  xmlns:rdf="&rdf;#"
  xmlns:rdfs="&rdfs;#"
  xmlns:owl="&owl;#"
  xmlns:xsd="&xsd;#"
  xmlns:geoProfile="&geoProfile;#"
  xmlns:ogc-gml="&ogc-gml;#"
  xml:base="&DEFAULT;#"
  xmlns="&DEFAULT;#">
<!-- In the Ontology Headers area, import
GeoProfile and ogc-gml.-->
<owl:Ontology rdf:about="">
  <owl:versionInfo>
    $Id: ExampleProfile.owl,v 1.0>
  </owl:versionInfo>
  <rdfs:comment>
    Example for OWL-S Geographic Profile
  </rdfs:comment>
  <owl:imports
rdf:resource="&service;" />
  <owl:imports
rdf:resource="&process;" />
  <owl:imports rdf:resource="&
GeoProfile;" />
  <owl:imports rdf:resource="&ogc-gml;"
/>
</owl:Ontology>
<!-- Geographic information is provided
below. For the location property, we use
ogc-gml coordinate system to indicate the
location.-->
<geoProfile:location>
< ogc-gml:Point>
  < ogc-gml:coordinates>
    -171.84805297851562,
    9.218889236450195
  </ ogc-gml:coordinates>
</ ogc-gml:Point>
</ geoProfile: location >
</rdf:RDF>

```

5. Usage of GeoProfile

In this paper, GeoProfile is extended based on Profile.owl for incorporating geographical information about the Web service. However, as the semantic Web service is still in its evolving stages, there are no tools to supply the extension of OWL-S. OWL-S proposes a proactive approach to Web service discovery which contrasts the passive approach exhibited by UDDI [12]. It provides more efficient delivery of advertised Web service profile to interested users. In order to enable automatic and intelligent invocation of services, OWL-S discovery

and execution elements include OWL-S Matchmaker and OWL-S Virtual Machine (VM) [11].

OWL-S Matchmaker plays the similar role as UDDI in traditional Web service. The OWL-S Matchmaker serves as a “catalog” of services defined using OWL-S. OWL-S descriptions of services are registered with the matchmaker. Client applications can then “query” the matchmaker with an ontological description of the inputs and outputs they desire. The matchmaker then matches the request against its catalog of services and returns a ranked list of services that most closely match the request sent by the client application.

The OWL-S Virtual Machine is utilised by client application to actually invoke services using OWL-S. The client application formulates its request using the format specified by the OWL ontology of the input and sends the request to the OWL-S Virtual Machine. Services defined in OWL-S are mapped to the actual Web Services they represent by way of the OWL-S grounding. Using XSLT transformations present in the grounding, the Virtual Machine reformats the request to match with the format required by the service, and then invokes the services on behalf of the client. When the response is received by the virtual machine, it uses another XSLT transformation in the grounding to reformat it into a format matching that of the output ontology and forwards it back to the client application. In this way, the client application does not need to know anything about how to interact with the actual Web service; the OWL-S Virtual Machine acts as a mediator for the request [11].

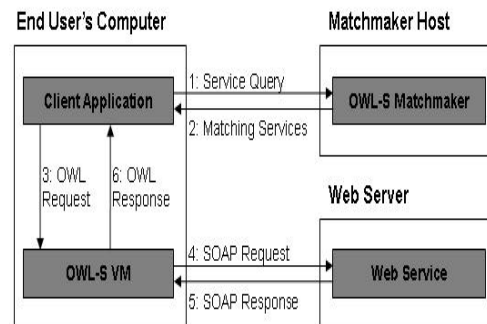


Figure 4: OWL-S Runtime Model [11]

The whole process of locating and invoking the services that uses OWL-S is shown in the figure 4. Therefore, GeoProfile not only enables the dynamic discovery of services based on the ontological classifications of the desired inputs and outputs inherited from Profile.owl, but also allows geographic information to match relevant Web service by extending it with geographical ontology. With the robust and comprehensive geographical

ontology from the OGC-GML, OWL-S Matchmaker can match services based on the ontological classifications of their inputs and outputs. This is essential to implement the transparency for client to use coordinate identifier (e.g. latitude, longitude) or geographic identifier (e.g. a postal code number) [10].

In our project scenario, suppose we provide a service to find the nearest Web service meeting client's requirement. This process is described in figure 5:

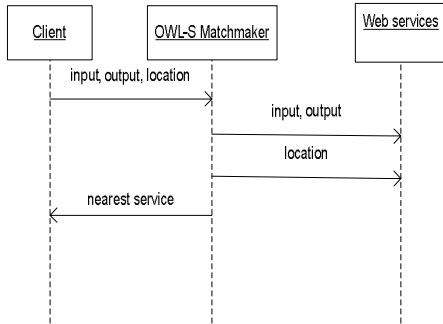


Figure 5: GeoProfile Usage Scenario

The major steps in this scenario are: 1) Clients send their request to OWL-S Matchmaker, including input, output and location information; 2) OWL-S Matchmaker finds all the services that match the input and output; 3) OWL-S Matchmaker then reads the location information of services described in GeoProfile.owl. Comparing it with the client's location information, and determines the nearest service; 4) Return this service to Client.

As we mentioned in section 4.3, the metric of "DistanceRange" is often viewed as a basic criterion to choose appropriate peer to invoke requested services, and it can be set according to different service requirements so as to indicate different levels of service accessibility. For example, the following is an algorithm to implement the selection of a nearest peer in a typical peer-to-peer application scenario, where invocations of Web services are assigned as tasks to a set of peers by extending an earlier SwinDeW-B system [16]:

```

Begin Function selectNearestPeer (GeoProfile)
if (Peer.Distance < DistanceRange) then
  add the peer into a arraylist P;
  if (sizeOfList > 1) then
    minDistance = P[0].Distance;
    for i ← 0 to i < N + 1 do
      if (P[i].Distance < minDistance) then
        minDistance = P[i].Distance;
      end if
    end for
  end if
end if

```

```

    return the peer who has minDistance;
  end if
else
    return the peer;
  end if
else
    return null;
  end if
end function

```

In the SwinDeW-B prototype, at first, each peer would calculate their own location information stored in their own Geo Profile to obtain their distance metrics from the service provider or requester. Then the peers will check whether their distance metrics meet the requirements set by the service's Geo Profile. The satisfying peers then will compare in a negotiation manner to decide which the nearest peer is, i.e., the best peer to invoke the relevant service [16].

In real services application, our defined GeoProfile has rich semantic features, through which the selection of Web services can be more intelligent in considering the location perspectives. Using OWL-S for the description of Web services can increase the ability of computer systems to find eligible services autonomously and rationally. This is important in open environments where provided services can appear and disappear dynamically. In figure 6, we describe the principle of our methodology at a higher level. The OWL-S matchmaker is a core part, by which different sorts of advertised services can be matched effectively with suitable matching algorithms, and the geographic considerations are expressed by OWL-S descriptions.

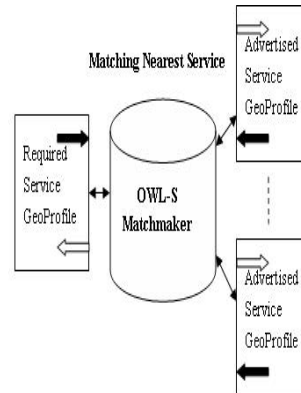


Figure 6: Selecting services with GeoProfile

6. Conclusion and Future Work

Semantic Web services are being accepted as the solution for dynamically realising Web services discovery and automated composition, and it is capable to provide extra information for LBS and other services. In this paper, we analyse and evaluate

the existing approaches to Location Based Web Service and propose a more flexible method. Compared with other research efforts in the area, we have shown two steps to enable Web service with semantic description to provide geographic information for LBS: geographical ontologies and semantic Web service descriptions using OWL-S. In particular, the geographic ontology we employed is based on GML since being widely accepted. Furthermore, the approach to extend OWL-S is updated to follow the new specification. On the basis of identified problems and limitations of the existing work, the extension method we have presented is also convincing for further concrete application developments.

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