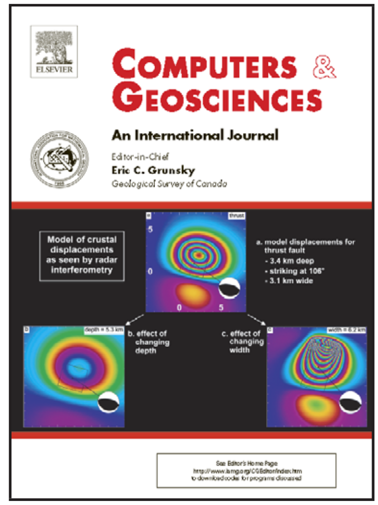
Author's Accepted Manuscript



www.elsevier.com/locate/cageo

Towards a semantics-based approach in the development of geographic portals

Nikolaos Athanasis, Kostas Kalabokidis, Michail Vaitis, Nikolaos Soulakellis

PII: S0098-3004(08)00152-0
DOI: doi:10.1016/j.cageo.2008.01.014
Reference: CAGEO 2029

To appear in: *Computers & Geosciences*

Received date: 3 April 2007
Revised date: 2 January 2008
Accepted date: 6 January 2008

Cite this article as: Nikolaos Athanasis, Kostas Kalabokidis, Michail Vaitis and Nikolaos Soulakellis, Towards a semantics-based approach in the development of geographic portals, *Computers & Geosciences* (2008), doi:10.1016/j.cageo.2008.01.014

Towards a semantics-based approach in the development of geographic portals

Nikolaos Athanasis*, Kostas Kalabokidis, Michail Vaitis, Nikolaos Soulakellis

Department of Geography, University of the Aegean, GR-811 00 Mytilene, Greece
*Corresponding author: email geod04002@geo.aegean.gr

Abstract. As the demand for geospatial data increases, the lack of efficient ways to find suitable information becomes critical. In this paper, a new methodology for knowledge discovery in geographic portals is presented. Based on the Semantic Web, our approach exploits the Resource Description Framework (RDF) in order to describe the geoportal's information with ontology-based metadata. When users traverse from page to page in the portal, they take advantage of the metadata infrastructure to navigate easily through data of interest. New metadata descriptions are published in the geoportal according to the RDF schemas.

Keywords: geoportal; semantic web; RDF; metadata; navigation

1 Introduction

The emergence of World Wide Web opened the way for the development of web-based systems which permit users to search, view, combine, query and operate on spatial data over the internet. These systems have been enhanced with sophisticated capabilities (i.e. map viewers, query gazetteers, geographic information services, route finding tools, geo-coding tools, etc.) and are popularly termed geographic portals (or geoportals for simplicity). Geoportals are gateways to spatial information (Maguire and Longley, 2005), providing integrated access to knowledge, including maps, applications, geographic web services, analytical models, reports, as well as related text material, dissemination articles, and journal papers.

Geographic portals act as 'negotiators' between users and information providers, following the "publish-find-bind" pattern (Fig. 1) of web service architecture (Ostensen and Smits, 2002). Providers offer data, applications or services by publishing to the geoportal corresponding declarative metadata (i.e. information that describes the data characteristics) through appropriate Geographic Information System (GIS) tools (e.g. ESRI's ArcCatalog™) or in some cases through the web site of the geoportal itself. Corresponding metadata standards, like the Content Standard for Digital Geospatial Metadata (Lee and Chan, 2000) of the Federal Geographic Data Committee (FGDC), or the ISO 19115 standard (Ostensen and Smits, 2002), have been developed, which define the content, quality, condition, origin, and other characteristics of spatial data. The geoportal receives the metadata published by the information providers and organizes them in a metadata catalogue. Users search for suitable information, needed to solve the problem at hand, by querying the portal's metadata catalogue for relevant matches. The results are accessible at the providers' side for viewing or downloading.

Nevertheless, the open and distributed nature of geoportal environments still present challenges for information discovery. In general, searching for information in geoportals is mainly based on querying according to spatial, thematic or temporal keywords. Once the query results are presented, users can visit the provider's site to view/download the results, access it through a live web mapping service (e.g. Geography Network's ArcExplorer^{TM} Web Service), view its metadata or start a new search process by refining the searching criteria. This approach, however, has some difficulties – especially for novice portal users – who may not know which keywords to use, have too little information on how to fill in interactive forms, or find it difficult to estimate how many filter criteria to be utilized (Hochmair, 2005). There are situations where navigation (i.e. browsing through hyperlinked pages) is more appropriate than querying such as where users have no clear idea of their information need, or they are not proficient with the keyword-based techniques provided (Lucarella and Zanzi, 1996).

Similar problems appear because of interoperability issues where the usability of information created in one context is often of limited use in another context, due to insufficient means for meaningful interpretation (Bernard *et al.*, 2003), a problem widely known as semantic heterogeneity. The definition of the Geography Markup Language (Lake *et al.*, 2004), and the standardization of service interfaces, like Web Feature Service (WFS) or Web Map Service (WMS) (Zhao *et al.*, 2004), increase interoperability at system, syntactic, and structural/schematic level, but do not cope sufficiently with interoperability issues at the semantic level. Searching for information are often prone to both low recall, where not all relevant information sources are discovered, or low precision, where some of the discovered data are not relevant (Klein and Bernstein, 2002). Semantic heterogeneity is caused by different conceptualizations and database representations of real world facts (Bishr, 1998). It can be separated into 'cognitive heterogeneity' where different perspectives on the same real world facts lead to different definitions between different domains and 'naming heterogeneity' where the same real world facts are named differently.

In addition, providers in a geoportal often need to describe the metadata they publish with characteristics that do not belong to any geospatial metadata standard. In a geoportal for disaster management for example, a possible characteristic could be the date a disaster (e.g. wildfire or flood) happened or the vegetation type of a burnt area, in case of a fire. Even though these characteristics could be specified in a shape file, such information does not belong to any geospatial metadata standard. Consequently, users often do not find what they are looking for, because querying in the portal catalog depends on the specific elements of the geospatial metadata standards. A data community can customize the base of the metadata standard by using extensions or metadata profiles, i.e. adaptations of the standard that may specify particular domain values and/or increase conditionality of a specific element. Nevertheless, even with these extensions and adaptations, semantic discrepancies are still an open issue.

The Semantic Web (Berners-Lee *et al.*, 2001), an extension of the World Wide Web in which information is given well-defined meaning, can provide useful answers to the aforementioned issues. A key to this approach is the use of ontologies, a descriptive approach dealing with the nature of being - *ontology*. Ontologies are perfect candidates for communicating a shared and common understanding (between people and computers) of some domain of discourse (Studer *et al.*, 1998), as they constitute formal and explicit specifications of a shared conceptualization of the domain (Gruber, 1993). Formal meaning that each term is defined by particular language with well-understood properties, while conceptualization refers to an abstract model of how people think about a real thing in the world. Explicit specification means that the concepts and relations of this abstract model have been given explicit names and definitions (Bernard *et al.* 2003).

Ontology-based approaches have already been applied in the domain of geospatial data (for example, Klien *et al.*, 2005). However, the contribution of the Semantic Web in the area of knowledge discovery in geographic portals is still limited. This paper presents an innovative approach for metadata organization and management in geoportals on the following issues:

- Users find it hard to specify the appropriate search criteria in order to find what they are looking for;
- The expressiveness of queries is limited by the set of elements of the geospatial metadata standards;
- Querying techniques based on keywords are unable to capture the semantics of information and thus knowledge discovery in geoportals suffer from semantic heterogeneity issues; and
- Querying results depend on the specific elements of the geospatial metadata standards (e.g. ISO 19115 or FGDC).

Taken these issues into account, we propose a new methodology for knowledge discovery in geoportals. When users navigate in the portal's interface, they take advantage of the ontology-based metadata infrastructure to further discover data, applications or services close to their interest. More specifically, our approach:

- Provides the means to describe the geoportal's information with ontology-based metadata by using the Resource Description Framework (RDF); and
- Exploits the ontology-based metadata organization to enhance users' navigation in the geoportal interface.

2 Related Work

The growth of geoportals is described by Maguire and Longley (2005). Some of the commercial geoportals include data from all over the world, like the Geospatial One-Stop and the Geography Network (Tait, 2005). Other geoportals handle data about specific regions and countries, like the Canadian geoportal *Mapster* and the *geoNorge* national map portal of Norway (Tang and Selwood, 2005). Many commercial geoportals are focused on specific application domains; for example, natural disasters geoportals, like the Pacific Disaster Center (Tang and Selwood, 2005) and the geoportal of the Federal Emergency Management Agency (FEMA) (Walker and Maidment, 2006), or health geoportals, like the South Carolina Community Assessment Network (SCAN) (Tang and Selwood, 2005). Nevertheless their users often get confused with what kind of search criteria to use while semantic heterogeneities often obstruct them to find the appropriate information, due to the use of conventional keyword-based techniques.

Beyond commercial systems, ontology-based approaches are often followed to cope with semantic heterogeneity issues in geospatial data. Klien *et al.* (2005) present a methodology for ontology-based service discovery; they propose a user interface called *Query Templates* that allows users to construct queries based on the concepts of the ontology. Nevertheless, these templates limit the range of expression of possible user queries. Lutz and Klien (2006) describe an improvement where users select terms from existing domain ontologies to formulate a query. A similar system is introduced in Ram *et al.* (2001). It provides an interface where users can query distributed spatial/temporal datasets, while Wiegand *et al.* (2004) propose a querying system for semantically heterogeneous government spatial data. In the same context, Córcoles and González (2004) introduce an approach to provide users with a unique interface for querying spatial XML resources using RDF, while Lemmens and de By (2002) propose an ontology-based framework to provide interoperability between datasets and operations. All of these approaches deal with the general problem of finding suitable geospatial information among large and distributed environments. They all identify semantic heterogeneity issues and propose ontology-based solutions. However, they are restricted to query formulation only and do not provide the means to combine querying with navigation during information discovery.

Navigation techniques to access data of interest through both query formulation and browsing have been proposed in the context of semantic web portals, like the RDF Distillery (Gibson, 2002), the OntoWeb (Spyns *et al.*, 2002), the OntoPortal (Carr *et al.*, 2001), and the ODESeW (Corcho *et al.*, 2003). These visual browsing interfaces offer a graphical view of the entire ontology as a tree or a graph of related classes and properties, where users can either access directly the resources classified or formulate filtering queries. Other semantic web portals include the ICS-FORTH Semantic Web Portal (Athanasis *et al.*, 2004), as well as the Semantic Web Portal for peer-to-peer e-learning (Kotzinos *et al.*, 2005). Compared with our system, these portals are also ontology-based, but they are not targeted at the geospatial information domain. Even though they exploit ontology languages like RDF and the Ontology Web Language-OWL, the development of semantics-based geoportals must also take into account specific issues concerning geospatial data, i.e. spatial map manipulation, spatial metadata and spatial operators/relationships over the data.

3 Methodology

We use the Resource Description Framework (RDF) to represent the geoportal's metadata. RDF is a framework for describing and processing metadata. It allows descriptions of any data item by using a Uniform Resource Identifier (URI), called a resource, in a machine-understandable form. The objective is to enable the definition of resource descriptions in an interoperable way, without making any assumptions about the domain or the structure of the described information (Karvounarakis *et al.*, 2003).

RDF describes the relationships among resources in terms of named properties and values. These properties may be thought of as attributes of the resources, while their values may be another resource or a literal value (i.e. simple string or other XML primitive data types like *String*, *Integer* etc.). Descriptions of RDF resources are represented as directed labelled graphs, also called nodes and arcs diagrams. The arcs represent the named properties, each of them connecting two nodes, coming from a resource (drawn as an oval) and pointing to another resource or a literal value (drawn as a rectangle). To accommodate the definition of descriptions, RDF is enhanced with a Schema Definition Language (RDF Schema - RDF/S) at a higher level of abstraction. At the RDF/S level, classes represent abstract entities referring to sets of similar resources, while properties represent attributes or relationships among classes. Resources are classified under (i.e. are instances-of) only one class of the schema; however each resource can be classified under different classes that belong to different schemas (multiple classification).

The proposed RDF-based metadata organization provides the means to assign explicit and machine-interpretable meaning in the geoportal's metadata. Several RDF schemas build the semantic backbone of the portal, a methodology also proposed by Wiegand (2007). In this work, they suggest using multiple ontologies in addition to a theme-based ontology. In a similar way, we suggest some of the schemas to be domain-dependent and specialized in the specific context of the portal (e.g. content type schemas), while other to be domain-independent, e.g. schemas that represent the elements of geospatial metadata standards (e.g. ISO 19115 or FGDC). Our proposed metadata organization does not only provide compatibility with current metadata standards, but is also readily extendable. Many reusable schemas already developed by different geospatial communities can be part of the semantic backbone of the portal.

New metadata descriptions are published in the geoportal according to the RDF schemas in a way that hides the complexity of the required procedure from information providers. Through the graphical user interface of the geoportal, information providers fill in the characteristics of new resources, define their (possible) relationships between related resources and classify them under specific categories that correspond to the RDF classes of the portal's metadata schemas. The geoportal receives the metadata submitted, automatically translates them into RDF metadata descriptions and adds them to the existing semantic metadata infrastructure.

Based on this ontology-based metadata organization, the geoportal offers "intelligent" navigation mechanisms that exploit the data semantics in order to make information discovery more accurate and efficient. We use the semantic query language RQL (RDF Query Language) to query the portal's metadata. RQL is a typed semantic query language based on a functional approach. RQL relies on a formal graph model (as opposed to other triple-based RDF query languages – e.g. (Miller *et al.*, 2002), (Sintek and Decker, 2001), (Pérez de Laborda and Conrad, 2005) - that permits the interpretation of resource descriptions by means of one or more schemas (Karvounarakis *et al.*, 2003). Furthermore, RQL enables users to access data, applications or services with minimal knowledge of the portal's schemas. In our approach, this feature is exploited to dynamically construct RQL queries as users navigate in the portal. At each navigation step, the resources provided correspond to the RQL query results for each of these dynamically created RQL queries. Users "mine" more data of interest, by further navigating to (semantic) related information. When users get a list of the resources that match with their querying criteria, the portal automatically detects all relationships from or to every resource found (according to the RDF-based metadata organization) and displays a "see related" hyperlink pointing to the target or to the source of each relationship. By activating these hyperlinks, users can easily navigate through data of interest.

The administrator of the geoportal is responsible for the creation and maintenance of the portal's RDF schemas. To ensure consistency, providers cannot submit new schemas; however they can publish new metadata according to the RDF schemas, while simple users can only query and search for resources of interest. For the creation and maintenance of the RDF-based metadata infrastructure we utilize the ICS-FORTH RDFSuite (Alexaki *et al.*, 2001) that enables the validation, storage and querying of the RDF metadata (both schemas and data descriptions). RDFSuite uses the RDF Schema Specific Data Base (RSSDB) for the storage of the RDF schemas and descriptions. The metadata are stored in PostgreSQL (Stonebraker, 1990), an open-source object-relational database management system.

4 A Running Example: The Geoportal of Natural Disasters

The approach proposed for information discovery in geoportals has been applied in an experimental geoportal about natural disasters. Its purpose is the dissemination of geospatial information concerning wildfires and floods for the region of northern Aegean Archipelago, Greece. The participating agencies are currently the Department of Geography of the University of the Aegean, the Forest Service of Lesvos Island and the Region of North Aegean.

Fig. 2 illustrates the metadata infrastructure of the experimental geoportal. For simplicity reasons, only a part of the descriptions about two resources and only a small subset of the portal's schemas are shown. Three RDF schemas build its semantic backbone.

The first schema (s1) describes the content type of each resource. The two most general classes in this schema are *Geographic_Info* and *Text_material.* Class *Geographic_Info* is specialized to sub-classes *Shapefile* (i.e. points, lines and polygons) and *Imagery* (i.e. Digital Elevation Models, orthophotos, topographic maps etc.). Each of these classes holds some attributes (e.g. attribute *pixel_size* for class Imagery) or relationships with other classes, (e.g. relationship *related_docs* between classes *Geographic_Info* and *Text_material)*. Class *Article* (i.e. subclass of *Text_material*) carries characteristics like *title* and *creator.*

The second schema (s2) of the geoportal is about natural hazards. In the example presented here, it consists of the generic class *Hazard* and its sub-classes *Fire* and *Flood*. Resources classified under class *Fire* carry the *vegetation_type* characteristic, but also inherit the characteristic *date_of_hazard* from the generic class *Hazard*.

The third schema (s3) is about the mandatory elements of the ISO 19115 metadata standard (i.e. *abstract, data set title, topic category, reference date, dataset language, point of contact*). It is created based on a geospatial ontology that describes the ISO 19115 metadata[1].

[1] http://loki.cae.drexel.edu/~wbs/ontology/2004/09/iso-19115.owl

Fig. 2 also illustrates the descriptions about two resources. Resource r1 is classified under three different classes (multiple classified); it is classified under class *Ortho-photo* of the content type schema and related with article r2, which is a resource classified under class *Article* of the same schema. It is also classified under class *ISO_19115* and holds values derived from the ISO 19115 metadata standard. Finally, resource r1 is also classified under class *Fire* of schema s3 to describe a fire hazard that happened on 27/08/2003 (property: *date_of_disaster*) and burnt an area of "pinus brutia" (property: *vegetation_type*).

When users navigate in the portal's interface, they take advantage of the semantics-based infrastructure to discover easily data of interest. A generic picture of our portal's layout is illustrated in Fig. 3. The left part provides an entry point to the portal. It shows the classes of the portal's RDF schemas, graphically visualized in a tree-based form that represents the "is-a" hierarchies of each schema's classes. Next to the tree-based hierarchies of the data categories, the portal represents a general map, where users can interact (i.e. zoom in/out, pan etc.) and specify the extent where data will be found, a common feature that can be found in all commercial geoportals. For each data category selected, users can apply filtering criteria on the attributes of the corresponding RDF class. In Fig. 3 for example, the user has selected *Fire* as data category and specified that she/he is looking for fires where the date the event happened was 27/08/2003.

When the "Search!" button is pressed, the portal returns the resources that match the search criteria. Each resource found is presented in a row of a table (Fig. 3). Users can download each resource found and see its metadata. In case of long metadata values (e.g. the abstract of an article), the geoportal provides hyperlinks that show the whole metadata entry in a separate new window. For each resource that matches the user's search criteria, the geoportal "suggests" (possible) relevant resources that can be viewed by activating corresponding "see related" hyperlinks. By following these hyperlinks, the portal enables users to traverse through its hyperlinked pages and find further data of interest. These hyperlinks point to the targets of relationships between the resources according to the RDF-based metadata (Fig. 2). As a consequence, a user's navigation follows the semantics-based metadata organization. The richer the metadata are, the easier the information discovery in the geoportal becomes. In Fig. 3, the hyperlink "see related Article" corresponds to the relationship *related_docs* between resources r1 and r2. If a resource is connected with more than one resource, then an appropriate "see related" link for each relationship is provided. Next to each "see related" link, the portal shows the corresponding relationship between the two resources as well, but only if there are more than one relationship between the same couple of resources. By activating the "see related Article" hyperlink (Fig. 3), the user can navigate to information about the article r2. In a similar way, the user can continue her/his navigation to further data of interest.

All new resources published in the geoportal carry the appropriate semantics, based on the portal's RDF schemas. Providers can fill in metadata descriptions through the portal's interface and submit the metadata to the geoportal where its metadata catalogue is updated by adding new RDF metadata descriptions. After this step, the new resources are available to the users for searching and navigation. The procedure of publishing a new resource in the experimental geoportal is illustrated in Fig. 4. For every selection of a data category the geoportal represents text fields that correspond to the characteristics of the corresponding RDF schema class. The provider then fills in the characteristics of the new resource, specifies its URI and defines possible relationships between this resource and other related resources that have already been published. Each resource can be classified under more than one class of different RDF schemas by selecting the appropriate check box next to each data category. For each category, the user defines the metadata values and possible relationships for this resource with other resources. Users can also specify the relationship between couples of related resources, when more than one property relates the same couple. In the screenshot of Fig. 4, a provider publishes a new article resource with URI http://195.251.137.181/article2.doc. He also specifies its title, the creator and defines its relationship with orthophoto http://195.251.137.181/orthophoto.tiff (resource r1).

Every browsing or querying action in the geoportal is transformed into a corresponding RQL query, in a way transparent to the user. In our geoportal prototype, appropriate RQL queries are executed whenever the "Search!" button is pressed, or whenever a "see related" hyperlink is activated. RQL queries are provided in a SQL-like "select-from-where" pattern. For example, the RQL query to find fires that happened on 27/08/2003 would be:

```
select X
from Fires{X}
where date_of_disaster = '27/07/2007'
```

Likewise, when the user activates a "see related" hyperlink, a similar RQL query is evaluated. The "see related" hyperlink of Fig. 3 for example corresponds to the evaluation of the following query:

```
select Y
from {X;Fire}related_docs{Y;Article}
where X like 'http://195.251.137.181/orthophoto.tiff'
```

This query will find all *articles* that are related with the property *related_docs* with the resource http://195.251.137.181/orthophoto.tiff. Similar RQL queries are dynamically constructed every time users traverse from page to page using the "see related" hyperlinks.

5 Concluding Remarks

In this paper, we presented an innovative approach for knowledge discovery in geographic portals (geoportals), based on the Semantic Web. Users often encounter difficulties in finding information because of the conventional keyword-based techniques followed. Semantic heterogeneity issues and limited expressiveness of conventional metadata standards also obstruct users when they search for specific spatial data, applications or services. In contrast, our approach takes advantage of the semantics-based metadata organization and provides navigation (i.e. browsing) mechanisms that exploit the data semantics in order to make information discovery more accurate and efficient. These mechanisms exploit the semantic query language RQL (RDF Query Language), on the semantic organization of the underlying metadata. Our approach also enables the registration of new geospatial resources in a way that hides the complexity of the required procedure from information providers. The geoportal receives the metadata submitted, automatically translates them into RDF statements and adds them to the existing semantic metadata infrastructure.

We are currently testing the usability of our first prototype geoportal about natural disasters in the area of northern Aegean Archipelago, Greece. The initial focus is to enhance the portal's functionality to support spatial operators (i.e. cross, overlap, touch, buffer, union, intersection, etc.) over the resources provided. This will provide the means to the users to navigate not only for semantically but also for spatially related data. Finally, we plan to enrich our system to use alternative ontology languages, e.g. OWL.

6 Acknowledgments

This work has been partially supported by the European Union within the RTD project *AUTO-HAZARD PRO* and the INTEREG IIIC project *INCENDI*. The authors would like to thank two anonymous referees and Dr Peter F. Moore of GHD, Australia, for their helpful reviews in an earlier version of the manuscript.

REFERENCES

Alexaki, S., Christophides, V., Karvounarakis, G., Plexousakis, D., Tolle, K., 2001. The ICS-FORTH RDF Suite: managing voluminous RDF description Bases. In: Proceedings 2nd International Workshop on the Semantic Web (SemWeb2001), Hong Kong, pp. 1-13.

Athanasis, N., Christophides, V., Kotzinos D., 2004. Generating on the fly queries for the Semantic Web: The ICS-FORTH Graphical RQL Interface (GRQL). In: Proceedings 3rd International Semantic Web Conference (ISWC'04), Hiroshima, Japan, pp. 486-501.

Bernard, L., Einspanier, U., , Haubrock, S., Hübner, S., Kuhn, W., Lessing, R., Lutz, M., Visser, U., 2003. Ontologies for intelligent search and Semantic Translation in Spatial Data Infrastructures. Photogrammetrie-Fernerkundung-Geoinformation 6, 451-462.

Berners-Lee, T., Hendler, J., Lassila, O., 2001. The Semantic Web. Scientific American 184 (5), 34-43.

Bishr, Y., 1998. Overcoming the semantic and other barriers to GIS interoperability, International Journal of Geographical Information Science 124, 299–314.

Carr. L., Kampa. S., Miles-Board. T., 2001. MetaPortal Final Report: Building Ontological Hypermedia with the Ontoportal Framework. Intelligence, Agents, Multimedia Group(IAM), School of Electronics and Computer Science(ECS), University of Southampton, United Kingdom, 2002 pp.

Corcho, O., Gómez-Pérez, A., López-Cima, A., del Carmen Suárez-Figueroa, M., 2003. ODESeW: Automatic Generation of Knowledge Portals for Intranets and Extranets. Lecture Notes in Computer Science 2870, 802-817.

Córcoles, J. E., González, P., 2004. Using RDF to query spatial XML. In: Proceedings 4th International Conference on Web Engineering, ICWE 2004, Munich, Germany, pp. 316-329.

Gibson, D., 2002. The RDF Distillery, B.Sc. Thesis, School of Information Technology and Electrical Engineering, University of Queensland, Australia, 70 pp.

Gruber, T. R., 1993. A translation approach to portable ontology specifications. Knowledge Acquisition 5 (2), 199-220. doi: http://dx.doi.org/10.1006/knac.1993.1008

Hochmair, H., 2005. Ontology matching for spatial data retrieval from Internet portals. In: Proceedings of Geospatial Semantics, Lecture Notes in Computer Science 3799, Mexico City, Mexico pp. 166-182.

Karvounarakis, G., Magganaraki, A., Alexaki, S., Christophides, V., Plexousakis, D., Scholl, M., Tolle, K., 2003. Querying the Semantic Web with RQL. Computer Networks 42 (5), 617-640. doi: http://dx.doi.org/10.1016/S1389-1286(03)00227-5

Klein, M., Bernstein, A. 2004. Toward high-precision service retrieval. IEEE Internet Computing 8 (1), 30-36. doi:http://dx.doi.org/10.1109/MIC.2004.1260701

Klien, E., Lutz, M., Kuhn, W., 2005. Ontology-based discovery of geographic information services. An application in disaster management. Computers, Environment and Urban Systems 30 (1), 102-123.

Kotzinos, D., Pediaditaki, S., Apostolidis, A., Athanasis, N., Christophides, V., 2005. Online curriculum on the Semantic Web: The CSD-UoC Portal for peer-to-peer e-learning. In: Proceedings 14th International World Wide Web Conference (WWW'05), Chiba, Japan, pp. 307-314.

Lake, R., Burggraf, D., Trninic, M., Rae, L., 2004. Geography Mark-Up Language: Foundation for the Geo-Web, 1st edn., John Wiley & Sons, 388 pp.

Lee, Y.C., Chan, H.C.E., 2000. Spatial metadata and its management. In: Proceedings of the International Symposium on spatial Data Quality, Geomatica 54 (4), pp. 451-462.

Lemmens, R.L.G., de By, R.A., 2002. Distributed GIS and metadata: methods for the description of interoperable GIS components. In: Proceedings of the International workshop on mobile and internet GIS, ISPRS Commission II Symposium, Working group 5, Wuhan, China, 9 pp.

Lucarella, D., Zanzi, A., 1996. A visual retrieval environment for hypermedia information systems. ACM Transaction of Information Systems 14 (1), 3-29. doi: http://doi.acm.org/10.1145/214174.214175.

Lutz, M., Klien, E., 2006. Ontology-based retrieval of geographic information. International Journal of Geographical Information Science 20 (3), 233-260.

Maguire, D. J., Longley, P. A., 2005. The emergence of geoportals and their role in spatial data infrastructures. Computers, Environment and Urban Systems 29 (1), 3-14.

Miller, L., Seaborne, A. Reggiori, A., 2002. Three Implementations of SquishQL, a Simple RDF Query Language. In: Proceedings 1st International Semantic Web Conference on the Semantic Web. I. Horrocks and J. A. Hendler, Eds. Lecture Notes In Computer Science 2342, Springer-Verlag, London, pp. 423-435.

Ostensen, O.M., Smits, P.C., 2002. ISO/TC211: Standardisation of geographic information and geo-informatics. Geoscience and Remote Sensing Symposium, IGARSS '02, IEEE International 1, 261-263.

Perez de Laborda, C., Conrad, S., 2006. Bringing relational data into the Semantic-Web using SPARQL and Relational.OWL. In: Proceedings 22nd International Conference on Data Engineering Workshops, ICDEW, IEEE Computer Society, Washington, DC, pp. 55. doi: http://dx.doi.org/10.1109/ICDEW.2006.37

Ram, S., Khatri, V., Zhang, L., Zeng, D. D., 2002. GeoCosm: A semantics-based approach for information integration of geospatial data. In Revised Papers from the Humacs, Daswis, Ecomo, and DAMA on ER 2001 Workshops. Lecture Notes in Computer Science 2465, 152-165.

Sintek, M., Decker, S., 2002. TRIPLE - A Query, Inference, and Transformation Language for the Semantic Web. In: Proceedings 1st International Semantic Web Conference on the Semantic Web, I. Horrocks and J. A. Hendler, Eds. Lecture Notes In Computer Science 2342, 364-378.

Spyns, P., Oberle D., Volz, R., Zheng, Z., Jarrar, M., Sure, Y., Studer, R., Meersman, R., 2002. OntoWeb - a Semantic Web community portal. In: Proceedings 4th International Conference on Practical Aspects of Knowledge Management. D. Karagiannis and U. Reimer, Eds. Lecture Notes In Computer Science 2569, 189-200.

Stonebraker, M., 1987. The design of the POSTGRES storage system. In: Proceedings 13th International Conference on Very Large Data Bases. P. M. Stocker, W. Kent, and P. Hammersley, Eds. Very Large Data Bases. Morgan Kaufmann Publishers, San Francisco, CA, USA, pp. 289-300.

Studer, R., Benjamins,V. R., Fensel, D., 1998. Knowledge Engineering: Principles and Methods, IEEE Transactions and Data on Knowledge Engineering, 25 (1-2), 161-197.

Tait, M.G., 2005. Implementing geoportals: Applications of distributed GIS. Computers, Environment and Urban Systems 29 (1), 33–47.

Tang, W., Selwood, J., 2005. Spatial Portals, 1st edn., ESRI Press, Redlands, 196 pp.

Walker, W.S., Maidment, D.R., 2006. Geodatabase design for FEMA flood hazard studies, Technical Report, University of Texas at Austin, USA, Center for Research in Water Resources 6 (10), 197 pp.

Wiegand, N., 2007. Semantic web for geospatial e-government portals. In: Proceedings of the 8th Annual international Conference on Digital Government Research: Bridging Disciplines & Domains, Philadelphia, Pennsylvania, USA, ACM International Conference Proceeding 228. Digital Government Society of North America, Philadelphia, Pennsylvania, pp. 298-299.

Wiegand, N., Zhou, N., Cruz, I. F., Sunna, W., 2004. A web query system for heterogeneous government data. In: Proceedings of the 2004 Annual National Conference on Digital Government Research, Seattle, WA, USA, ACM International Conference Proceeding 262, Digital Government Society of North America, Seattle, WA, pp. 1-10.

Zhao, P., Chen, A., Liu, Y., Di, L., Yang, W., Li, P., 2004. Grid metadata catalog service-based OGC web registry service. In: Proceedings 12th Annual ACM International Workshop on Geographic Information Systems, Washington DC, USA. GIS '04. ACM, New York, NY, USA, pp. 22-30. doi: http://doi.acm.org/10.1145/1032222.1032227.

Figure captions

Fig. 1- Relationship among geoportals, users and information providers in a geoportal infrastructure

Fig. 2- Metadata in experimental geoportal about natural disasters

Fig.3- A generic picture of portal's layout

Fig. 4- Interface for publishing new resources

Fig. 1

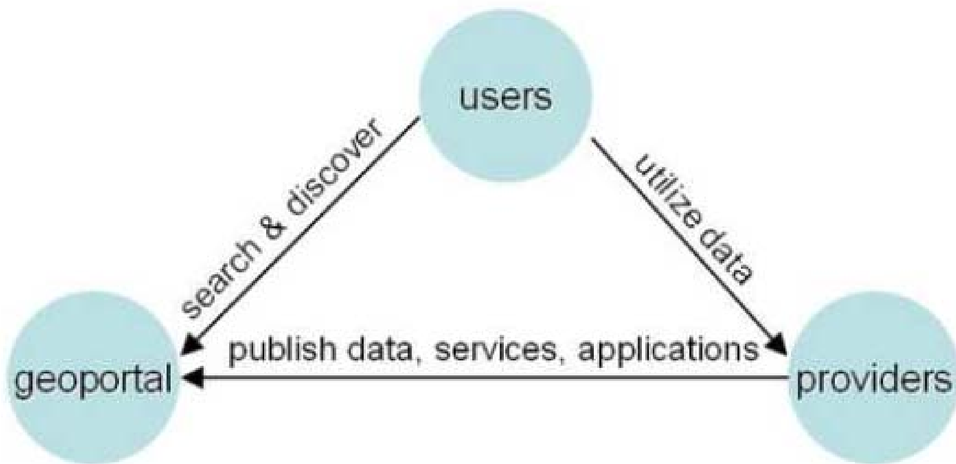

users
search & discover
utilize data
publish data, services, applications
geoportal
providers

Fig. 2

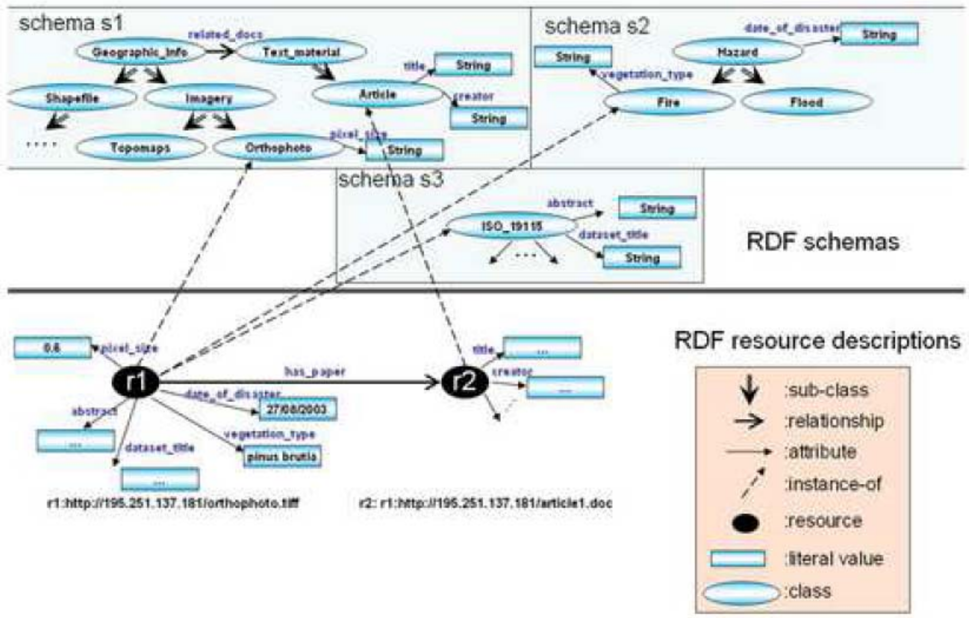

schema s1
schema s2
schema s3
RDF schemas
RDF resource descriptions
related_docs
Geographic_Info
Text_material
Shapefile
Imagery
Article
Topomaps
Orthophoto
title
creator
pixel_size
String
Hazard
Fire
Flood
date_of_disaster
vegetation_type
ISO_19115
abstract
dataset_title
r1
r2
has_paper
0.6
27/08/2003
pinus brutia
r1:http://195.251.137.181/orthophoto.tiff
r2: r1:http://195.251.137.181/article1.doc
:sub-class
:relationship
:attribute
:instance-of
:resource
:literal value
:class

Fig. 3


Geoportal
of
Natural Disasters
Data Categories
content type
Geographic_info
Shapefiles
Imageries
Orthophoto
Text_material
Article
natural disasters
Hazard
fire
flood
ISO 19115
filtering conditions
date_of_disaster
27/08/2003
vegetation type
Search
Clear fields
Resources found
content type schema
natural disasters schema
ISO 19115 schema
pixel_size
Date_of_disaster
vegetation_type
data set title
abstract
0.6
27/08/2003
pinus_brutia
Orthophoto about the wildfire of 27/08/2003 in Vatera, Lesvos island, Greece
Abstract

Fig. 4


Geoportal of Natural Disasters
Data Categories
content type
Geographic_info
Shapefiles
Imageries
Topomaps
Orthophoto
Text_material
Article
natural disasters
Hazard
Fire
Flood
ISO 19115
ISO 19115 metadata
Specify URI of new resource:
http://195.251.137.181/article2.doc
Specify relationship with:
Class
Orthophoto
Resource
http://195.251.137.181/orthophoto.tiff
title
Integrating new methods and tools in fire danger rating
creator
C. Vasilakos
Submit
Clear fields