Computer Science and Information Systems 12(3):1055–1078 DOI: 10.2298/CSIS141031010B

An Approach for the Development of Context-Driven Web Map Solutions Based on Interoperable GIS platform

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Abstract. In this paper we will define and describe a novel approach for the development of context-driven Web Map solutions. Our approach relies on an architecture we define and present in this paper as an enhancement of GIS application interoperability platforms. The enhancement is performed through introduction of a specific architectural layer which enables the development of context-driven Web Map solutions. A novel architectural layer we introduce consists of two central components: Web Map Context Service and Context Proposal Service. These services take advantage of existing GeoNis framework for interoperability of GIS applications and enable users get appropriately visualized geospatial data depending on their Web map context. The novel architectural layer performs externalization of Web map contexts in separate files complaint to Web Map Context Documents specification. Web map context files are used as configuration files to configure map display elements for each user. Rendering capabilities are also delegated to the client side which simplifies server components and improves system performances. The enhanced platform is capable of adapting to different users' needs without changing its internal structure and improves the level Web Map solution usability. Also, in this paper we will present an implementation of the proposed architecture and services with purpose of demonstrating the ability of our proposal to apply the existing GIS application interoperability platform for different Web map contexts and styles for viewing maps.

Keywords: GIS, interoperability, ontology, Web, context.

1. Introduction

Over the years, scientists and engineers have struggled to develop an interoperable geo-information dissemination environment through research and development in various fields of science: syntactic standardization of Web-accessible geo-information sources [1][2][3][4], semantic annotation of Web-accessible geo-information sources [5][6][7] and the development of ontology-driven geo-information integration architectures [8][9]. The Open Geospatial Consortium (OGC) has provided probably the most prominent contribution in the syntactic standardization domain. Their contribution was given in the form of standards for the geo-information Web services and data structures [1][2][3][4]. Since OGC standards are widely adopted and used in GIS architectures, research community devoted lots of attention to enhancing geospatial data source discovery in architectures relaying on these standards.

Discovering a suitable geo-information source for a particular user is a challenging task. Such task is particularly hard when implemented within Web Map solutions (Web Geographic Information System, Web GIS) which have a significant number of different users and rely on a number of heterogeneous information sources. Geospatial data source discovery process is particularly important if geospatial content should be filtered for a particular user, e.g. according to user's preferences. Each user expects Web Map solution to be capable of displaying a particular subset of geo-information and maps – the geo-information and maps he/she is currently interested in. For example, GIS is one of typical information systems used in the electrical power supply companies [56] and company employees will expect their Web Map solution to be capable of displaying, recording, discovering and analyzing the data regarding electric power supply network [57]. Among all available data (services, geospatial layers, documents, etc), Web GIS users need a mechanism to easily find (discover) what they are searching for – using their own words, their own language [10]. This information determine user context within Web Map (Web GIS) solution in terms of displayed geo-information and maps. For that reason, Web Map (Web GIS) should rely on an infrastructure which enables discovery and usage of appropriate geo-information sources, integration of information from appropriate geo-information sources and storing of user context information in terms of displayed geo-information and maps.

In most cases, geospatial data source discovery enhancement is performed through means of semantic annotation of geospatial data and Web services [8][7][11]. However, even in cases where ontologies are used for semantic annotation, recent researches like Tian and Huang [12] have demonstrated that these approaches are still highly dependent of transformation between UDDI and languages used for ontology development and can suffer from restricted semantic reasoning capabilities.

A novel approach, which we define and describe in this paper, foreseen to be used for these purposes, is an enhancement of GIS application interoperability platforms through introduction of a specific architectural layer which enables the development of Web Map context-based solutions. We have defined this layer by specifying and developing its two main components: Web Map Context Service (WMCS) and Context Proposal Service (CPS). Web Map Context Service is foreseen as a mediator between users and GIS application interoperability platforms. In particular, we will present an architecture which takes advantage of existing GeoNis framework for interoperability of GIS applications [13][14] to demonstrate the advantage introduced by WMCS and CPS services. Also, an implementation of the proposed architecture and services along with details regarding WMCS and CPS functionalities will be presented. The description of the implementation we performed demonstrates the ability of our proposal to apply the existing GIS application interoperability platform for different Web map contexts and styles for viewing maps. Additionally, we will demonstrate how WMCS helps users get appropriately visualized geospatial data depending on their Web map context. In the architecture we have developed, Web map context contains information used to configure map display elements and styles. As foreseen by our architecture, Web map context does not address personalizing display according to any other kind of (semi)automatically-obtained user preferences. User Web map context information is stored in a context document which is created according to Open Geospatial Consortium (OGC) specification. Context documents are created, maintained and manipulated through Web Map Context Service operations. The creation of the initial map context proposal of a new Web-based GIS user, based on the description of the data that the particular user is interested in, is the basic functionality of Context Proposal Service.

2. Related Work

While searching in Web GIS for the data they are interested in, individuals who do not belong to Geographic Information System (GIS) world expect to be provided with search results in the form of homogeneous data set(s) [10]. Resulting data sets are also expected to be shorn of any details regarding the data origin [10], which in most cases introduces a necessity to: perform integration of data and computation resources belonging to several autonomous systems [8][15][16], create a context for each user based on user's preferences [17] and personalize Web Map solution to reflect user context in terms of discovered data sets [18][19]. Each of the aforementioned tasks should represent one of the core functionalities of a context-driven Web Map solution.

From the standpoint of researchers contributing to GIS interoperability, the process of providing GIS users with data set(s) according to their Web map context can be interpreted as the process of discovering and accessing geospatial data integrated from heterogeneous and distributed geospatial data sources [8][12]. Previously reported approaches indicate that ontology-driven geo-information integration architectures can be effectively used as means for performing geospatial data integration [8]. Ontology-driven geo-information integration architectures (platforms) are designed to describe the semantics of geo-information sources and to make their content explicit through means of ontologies. They provide semantic reasoning capabilities and utilize ontologies for the discovery and retrieval of geo-information [8][15]. Mostly, the retrieval of geo-information is based on utilizing connections (mappings) between ontologies and geo-information sources [20][21][16]. Geo-information sources used within these architectures can be accessed through means of geospatial services conforming to OGC specifications [1][2][3][4]. Thus, if the geo-information sources within these architectures expose their interface in the form of Web services conforming to OGC specifications, then the problem discovering dataset(s) for a particular user can be transferred into the problem of discovering geo-information sources within ontology-driven geo-information integration architectures. In such situations, ontology-driven architecture would represent an excellent basis for the development of context-driven (Web) Map solutions.

Although context-driven (Web) Map solutions can be observed as closely related to geospatial data integration and GIS interoperability, previous research indicates they have been investigated independently, mostly within the following research areas: semantic annotation of Web-accessible geo-information sources, development of ontology-driven geo-information integration architectures and development of context-driven GIS solutions.

We would like to stress that the template should not be manipulated and that the guidelines regarding font sizes and format should be adhered to. This is to ensure that the end product is as homogeneous as possible.

2.1. Semantic annotation of Web-accessible geo-information sources

Semantic annotation of geospatial information and services has previously been thoroughly investigated as mean for overcoming semantic heterogeneity problems. The same mechanism was used for enabling geospatial data source discovery [15][22][23]. Scientific community has made significant effort in developing proposals on how to enrich geospatial Web services with semantics using ontologies [24][25][26]. A majority of proposals generates explicit relationship between the data schema and domain ontologies to perform semantic enrichment of geospatial Web services. For the purpose of modeling domain ontologies, formalized languages, such as Web Service Modeling Ontology (WSMO) or OWL-S [27][28][29], are used.

In the GIS domain, probably the most prominent contribution in semantically annotating Web services was given by the Open Geospatial Consortium (OGC). OGC proposed semantic annotation of Web services by proposing linking OGC capabilities documents to ontologies [7]. Recently, OGC also released OGC GeoSPARQL – a standard developed to support querying and representing geospatial data on the Semantic Web [30]. OGC GeoSPARQL adds an extension to the SPARQL query language for processing geospatial data and contains a vocabulary that can be used for representing geospatial data in RDF. Although scientific community considers these proposals to represent a significant contribution in the research of semantic annotation of Web services, there seems to be a lack of discovery systems developed on the bases of these proposals. Thus, the usability of OGC proposals is yet to be discovered.

Not all discovery systems in GIS domain utilize ontologies. Recently reported development indicates a growth in number of system implementations capable of discovering OGC services through UDDI interface [31] using service catalogs [6]. In time, service catalogues have grown into semantically-enhanced service registries. Such registries support semantic querying and use mappings between UDDI structures and OWL, OWL-S and WSMO constructs [32][5][33]. These registries enhance the capability to discover geospatial Web services, including OGC services. However, a majority of reported systems use different standards (OGC capabilities XML document, OWL, OWL-S, WSMO and UDDI) within different architectural tiers to express Web service characteristics. This can be considered to be a weakness since it results in every reported system being highly dependent on transformation between these standards. For that reason, semantic reasoning over the entire system becomes hard to implement.

2.2. Ontology-driven geo-information integration architectures

Ontology-driven geo-information integration architectures are considered to be powerful means for performing geospatial data integration. These architectures commonly utilize ontologies to solve geospatial data integration problems [8][34]. Ontologies resolve semantic heterogeneity by providing a shared comprehension of a given domain of interest [14][35]. Within information integration architectures, three different approaches for ontology usage can be identified: single ontology, multiple ontology and hybrid ontology approach [15]. Regardless of the approach used for the development, these architectures are expected to provide mechanisms for the discovery and retrieval of geo-information. Commonly, ontology-driven geo-information integration architectures rely on mappings between (global/local) ontologies and information sources to perform these tasks [8].

Since most data are currently stored in relational databases, a significant number of studies have been performed to develop methodologies which facilitate mapping between relational databases and local ontologies [16][36]. A survey conducted by W3C RDB2RDF Incubator Group [37] indicates that reported methodologies can be generally divided into two groups according to an approach used for mapping between RDB and local ontology: an approach which creates ontology from a database and an approach which introduces mapping between a database and an existing ontology. Among the solutions which belong to the first group, Triplify [38] stands out as a lightweight solution capable of revealing the semantic structures of the relational data structures behind Web applications by making database content available as RDF, JSON or Linked Data. As concerns the second group of solutions, after surveying the existing solutions W3C RDB2RDF Working Group has recently published their proposal for mapping relational databases to RDF. This proposal, named RDB2RDF Mapping Language [39], was made an official W3C candidate recommendation and it will hopefully become a standard. Although aforementioned solutions posses indisputable quality, there are still some shortcomings which should be addressed. For example, a majority of proposals from both groups is missing explicit support for geospatial data. Another common characteristic of these proposals is lack of an explicit definition of a discoverable Web geospatial service interface used to access the mapped data source.

Previous research and development indicate high maturity level of ontology-driven geo-information integration architectures. However, there are still some aspects regarding the characteristics of these architectures to be investigated. As stated in [8], “the nature of the representation of the geographic information is one of the main aspects that should be considered”. Only few reported architectures provide mechanisms to model the representation of the geographic information. This is particularly important in cases where these architectures represent a foundation for the development of context-driven (Web) Map solutions.

2.3. Context-driven GIS solutions

Context-driven Web Map solutions can be observed as a member of a group of personalized software. The fundamental problem of personalized software development is an approximation of user preferences with a little amount of relevant information [17]. This information represents the foundation of the user context. The reported techniques used for user context extraction are mostly based on determination of user preferences and categorization of users according to their behavior [18][40][19]. In the field of GIS methodologies, context-driven GIS have been studied mostly within the development of mobile applications [41][42]. These proposals emphasize the need for different levels of adaptation within the geospatial data presentation process [42][43], as well as the need for the development of methodologies that would consider different contextual dimensions together [13]. All together, these approaches share a goal – to make GIS able to automatically determine and derive its content.

Previously reported contextual cartographic visualization system proposals are in most cases based on client–server architecture. A solution for adaptive visualization of geospatial information on mobile devices proposed in [44] performs adaptive cartographic visualization on the server side. The limitations introduced by the environment of this system resulted in client being responsible only for the presentation of geospatial data [44]. If client would be capable of performing rendering of geo-information using different display styles, this would improve overall system performances in terms of reducing visualization functionalities delegated to server side. The context types used by this solution are predefined. Another proposal based on client-server architecture can be found in GiMoDig project [45]. The architecture of GiMoDig project uses extensions of OGC Web Map Service and OGC Web Feature Service specification. These extensions are introduced for the purpose of establishing communication between client and server sides. The elementary context types used by GiMoDig solution are invariant.

An implementation encountered in the field of contextual cartographic visualization which we consider in some extent similar to our proposal is named Sissi – Contextual Map Service [46]. Sissi is a Web-based server application which provides context-aware maps for Web GIS clients. Although it is also based on client-server architecture, Sissi differs in more that few characteristics when compared to previously described solutions. We consider these characteristics to be very significant. Sissi does not have a predefined set of elementary context types which is how it differs from the previously described solutions. This characteristic makes Sissi capable of supporting different contexts. Sissi specification represents an extension of Web Map Service specification with extending requests – *GetElementaryContextType* and *GetMapWindows*. Another difference compared to Web Map Service specification is the modification of *GetCapabilities* request in order to include an additional context parameter. Context parameter is used for user context encoding in the form comma-separated context values. Symbology used for the rendering of adapted (contextual) maps is an integral part of Sissi and is defined using Styled Layer Descriptor styling language [47].

Hereby presented contextual cartographic visualization solutions, which we consider to be the prominent ones, indicate that though significant research and development results exist in this field, a significant effort should be put into improving the usability of contextual cartographic visualization systems. For instance, although a majority of these systems rely upon the usage of OGC standards (mostly Web Map Service and Web Feature Service implementation specifications), user context information is not created and maintained according to the existing (OGC) standards which decreases the interoperability level of the presented systems. Also, a majority of adaptive cartographic visualization systems imposes a tight coupling between a map rendering services and symbology used for the visualization of geospatial information. Therefore, evaluated systems do not provide their users with ability to determine the styles which should be used for the visualization of geospatial information that they are interested in. Rather, the presented system uses internal style development formats or integrated Styled Layer Descriptor documents. Further, the usage of WFS services is not provisioned in the majority of these solutions. The direct usage of WFS services can be very significant if clients are capable of adapting geospatial data presentation according to the style provided on the basis of the user context.

3. An Architecture of Context-driven Web Map Solutions based on Interoperable GIS Architecture

The focus of the research presented in this paper was the development of a general architecture of contextual Web Map solution, with a purpose of improving the level of usability of contextual geospatial information visualization systems. The architecture we have developed takes advantage of the existing GIS application interoperability platforms for user context creation purposes. Our architecture relies on the GeoNis interoperability platform and its taxonomy to determine user preferences and perform "on-demand" integration of selected information from multiple heterogeneous information sources. Also, our architecture utilizes existing Web Map solution components and introduces an additional architectural layer which contains Web Geo-Information Services (Web GIServices) capable of supporting contextual geospatial visualization. A newly added layer does not influence the existing Web Map solution architectures, e.g. the omission of this layer will not influence the usual functioning of the existing Web Map solutions. Therefore, this layer will add contextual geospatial information visualization capabilities to the existing Web Map solutions without introducing any modification of the existing functionalities.

The main goal while specifying and developing architecture for contextual geospatial data visualization was to design a Web Map Context Service as a Web service that has an ability to integrate itself into the existing GIS environments in order to transform such systems into contextual geospatial visualization environments. Most of the existing GISs are built upon service-oriented architecture (SOA) principles and use GIService which provide geospatial data (such as Web Feature Service), perform visualization (such as Web Map Service) and maintain styles. WMCS is a Web service designed as a mediator between these services and end-users. Therefore, WMCS expects the following prerequisites to be fulfilled so that it can be integrated into an architecture for contextual geospatial data visualization: a semantic description of geospatial data sources must exist and data access interfaces should be implemented as Web services conforming to OGC specifications.

The main purpose of WMCS is to maintain the user context document and to combine the existing services according to user context information in order to provide users with the appropriate maps and features. The design of WMCS and its operating environment, along with additional Web services, was the main objective of our research and development. The result was named after the specification used for the development of context documents – Web Map Context Service.

Web Map Context Service is also designed as a context document repository and it does not have the capability to match user's preferences with the existing context. In order to allow context approximation, we propose another service that allows third-parties to customize this service with their own matching algorithm. The architecture of the system that WMCS operates in is shown in Figure 1.

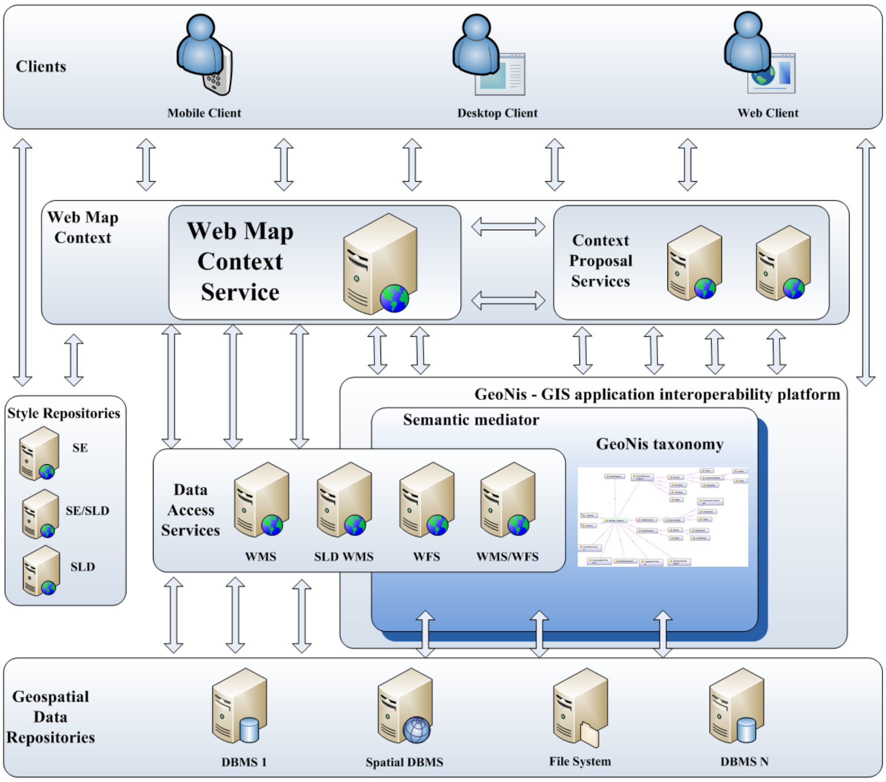

Fig.1. An architecture of context-driven Web Map solutions

GIS capable of performing map adaptation should consist of several components that perform all the tasks needed to help users to get appropriately visualized geospatial data depending on the user context:

- Clients (desktop, mobile, Web GIS) - GIS applications capable of displaying geospatial data in the form of electronic maps. Since clients should be capable of visualizing geospatial data appropriately, these applications have to be able to perform the following tasks: acquire context documents from WMCS, extract contextual data from the received documents, and create appropriate requests to services on the basis of the extracted data and to properly visualize received data.
- Web Map Context Service – Stand-alone Web service responsible for maintaining information considering all registered services and style repositories in the system. Furthermore, WMCS maintains information considering registered user Web map contexts and provides them to the clients and to the Context Proposal Service.
- Context Proposal Service – This service is capable of providing clients with specific context that describes the data and maps relevant to the users' interest.
- GeoNis – GIS application interoperability platform. Semantic interoperability in GeoNis, resolved by Semantic Mediator [48], is the ability of sharing geospatial

information at the application level, without knowing or, understanding terminology of other systems.

- OGC Web Map Services (WMS)[1] and Web Feature Services (WFS)[2] – Services developed according to OGC WMS and WFS standards. The geospatial data provided from these services is used in different contexts. Clients can request data from these services only if these services are registered within Web Map Context Service.
- Symbology Encoding Repository Services (SER Services) [54] – Services that provide styling documents developed using Styled Layer Descriptor [27] or Symbology Encoding styling language [49]. The information contained within these documents is used to instruct rendering engine how to perform visualization of particular geospatial data. Coupled with geospatial data, these documents are used for the purpose of creating and registering contexts within the Web Map Context Service.
- Geospatial data repositories – Different geospatial data sources (RDBMS, RDBMS with support for spatial data, NoSQL, File System etc.). These data sources are accessed through instances of Data Access Services.

Context-driven GIS architectures, including the proposed one, have shifted towards an agreement on a common interoperability architecture based on emerging GIS interoperability specifications, most of them issued by OGC. These specifications follow SOA principles and move GIS applications towards a distributed architecture based on interoperable GI services. Also, services developed according to OGC standards have standardized interfaces which provide GIS developers with a possibility to easily combine several services capable of processing and visualizing geospatial data. Combined with services that provide user context, e.g. WMCS instances, these services represent a solid foundation for the development of a distributed context-driven GIS. In this context, we consider our architectural proposal to be a significant step forward in terms of usability and modularity of contextual geospatial visualization environments.

3.1. WMCS and CPS – An Approach that Transforms Web Map Solution into a Context-driven Web Map Solutions

In the architecture we have developed, Web Map Context Service (WMCS) is the major component used for the development of context-driven Web Map solutions. The main purpose of the WMCS is to provide users with appropriate geospatial content relevant to user's context. WMCS is used as a mediator in the process of adaptation of geospatial data representation. For these purposes, WMCS is combined with GIS clients and distributed Web services that provide geospatial data and styling documents. These services need to be registered within WMCS before they can be used.

In cases where the context document contains a description of WMS service layers, a client creates an appropriate *GetMap* request according to the extracted information, sends the request to the WMS service and displays the resulting images. WMCS enables the usage of WMS services which support geospatial data styling according to Styled Layer Descriptor implementation specification, as well as WMS services which do not support user defined geospatial data styling. In cases where a WMS service which does not support SLD styling is used, users are not able to choose styles for layers, and they will receive images with a default style applied. If a WMS service supports SLD styling, clients need to embed the obtained symbology in the form of an SLD document into WMS *GetMap* request in order to receive an image with the appropriate symbology applied. This process is shown in Figure 2.

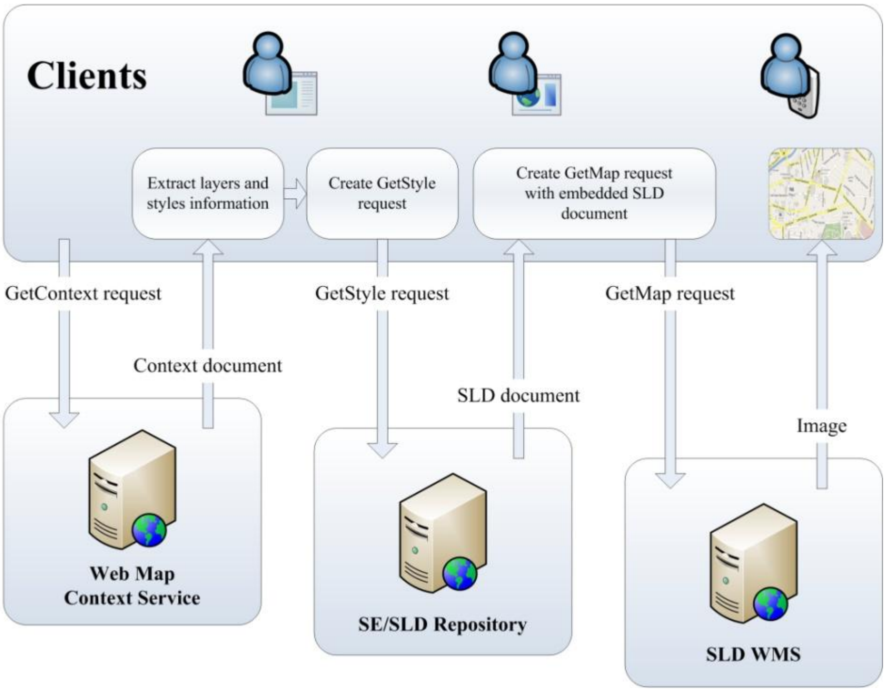

Fig.2. Communication between a client and the system in cases where the used WMS supports geospatial data styling

In order to visualize geospatial data acquired from the WFS service, clients need to have a mechanism which enables visualization of data acquired from WFS according to styles obtained from one of the Symbology Encoding Repository Services. This process is shown in Figure 3.

First, a client needs to send a *GetContext* request to the WMCS. After receiving a context document, according to the extracted information, the client creates and sends *GetFeature* request to WFS services and *GetStyle* request to SER Services. Finally, the data received from WFS services is visualized according to styles received from SER Services and displayed to user.

WMCS creates a context document for each registered context according to OGC Web Map Context Documents implementation specification [50]. Basic information considering users' contexts is stored in a database while the created context documents are being stored on the file system.

As previously stated, OGC Web Service Common Standard [51] was used as a starting point for the development of WMCS specification. According to this specification, the following operations have been specified:

- operation used in order to provide metadata regarding capabilities provided by WMCS service
- operation used in order to provide context documents to the clients

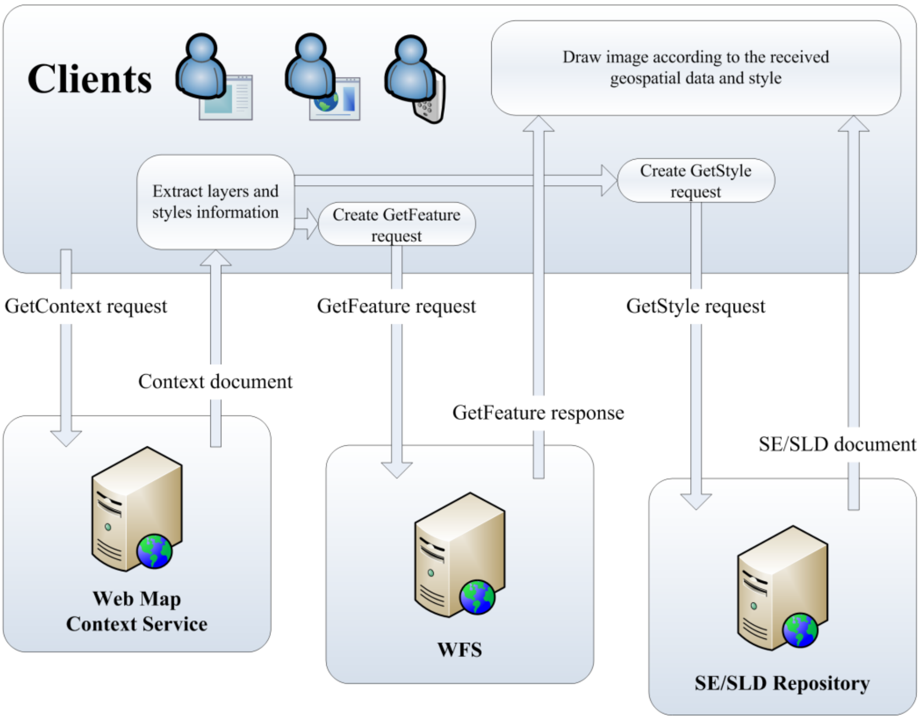

Fig.3. Communication between a client and the system in cases where a WFS service is used

WMCS specifies additional operations that are not specified by OGC Web Service Common Standard:

- operation used for registering services that provide geospatial data and styles (WMS, WFS, SER Services)
- operations used for manipulating user contexts
- operation used to obtain temporary context document from WMCS; temporary context document is a Web map context proposal for a new Web GIS application user based on the description of the data that the particular user is interested in; it represents a result of a matching process performed by Context Proposal Service and it will contain the names of WMS layers and/or WFS feature types which correspond to user-defined keywords

These operations represent the minimal WMCS operation set. All WMCS operations have the following parameters inherited from the Web Service Common Standard [51]:

- SERVICE – Service type identifier

- REQUEST – Operation name
- VERSION – Specification version for operation

If WMCS encounters an error while processing user requests, it shall return an exception report message as specified in Clause 8 of OGC Web Service Common Standard [51].

WMCS defines the following operations:

- **RegisterService** operation – WMCS allows registration of distributed Web services that provide geospatial data and styling documents through the RegisterService operation
- **GetCapabilities** operation – The *GetCapabilities* operation provides a client with metadata regarding the capabilities provided by WMCS service.
- **RegisterContext** operation – The *RegisterContext* operation provides users with the ability to register their context within WMCS.
- **GetContext** operation – The *GetContext* operation allows retrieval of a single or all context documents from WMCS.
- **UpdateContext** operation – The *UpdateContext* operation provides users with the ability to update the existing context within WMCS.
- **DeleteContext** operation – The *DeleteContext* operation allows the removing of the existing context from WMCS.
- **GetLayers** operation - The *GetLayers* operation allows retrieval of temporary context document from WMCS as a result of comparison of two term sets – a term set received as an argument of *GetLayers* operation and a term set which consists of the names of data layer which can be obtained from the WMSs and WFSs registered within WMCS. The resulting context document is not stored within WMCS service.

Besides the ability of obtaining the context document directly from the Web Map Context Service, client can obtain the context document from the Context Proposal Services (CPSs). CPS instances are considered to be integral parts of the proposed service-oriented architecture. CPS is a customizable service that can be implemented by a third-party. The basic functionality of CPS instance is the creation of the initial map context proposal of a new Web GIS application user based on the description of the data that the particular user is interested in.

The textual description of geographical entities which appear in WMS and WFS data layers, exposed through the data layer name, can be very different. These textual descriptions have to match user-defined keywords. Since textual descriptions of geographical entities, e.g. data layer names and keywords, will be used to identify the content suitable for a particular user, this will raise problems of using text strings in order to identify a geographical entity. These problems are well-known and are related mostly to synonymy and ambiguity. In order to partly overcome these problems, in the current development stage, a user-defined set of keywords is expanded by the CPS using WordNet lexical database [58]. For each of user-defined terms, CPS expands user-defined set of terms with synonyms, first level hyponyms and all terms in the hypernym tree obtained from WordNet lexical database. The resulting set of terms is compared with GeoNis taxonomy e.g. it is compared to the names of GeoNis global ontology concepts. Since GeoNis ontology concepts are mapped to geospatial information sources, that in turn can be accessed through WMS and WFS interfaces, the matching process result will contain the names of WMS layers and/or WFS feature types which correspond to global ontology concepts whose names are similar to user-defined terms. The resulting expanded set of terms is submitted to WMCS service by invoking *GetLayers*() operation of the WMCS service whose argument is the resulting term set.

The core of the geospatial data source discovery is a matching process, based on a similarity measurement performed between terms extracted from the user-defined geospatial data description and expanded by CPS, and GeoNis global ontology concepts. The matching process is performed by Context Proposal Service. Context Proposal Service will load GeoNis global ontology, extract ontology concepts and determine similarity between the expanded term set and the ontology concepts. The similarity measurement is based on the use of a combination of unsupervised word sense disambiguation methods, which utilize WordNet computational lexicon. The GeoNis global ontology concepts, whose similarity with user-defined terms exceeds a predefined threshold value, will be used to determine the names of WMS layers and/or WFS feature types which will be added to the resulting context document. This process is automatic due to GeoNis platform which contains mappings between concepts and data sources, which in turn expose the data through WMS and WFS services.

The similarity measurement between terms extracted from the user-defined geospatial data description and GeoNis global ontology concepts is performed in through the following steps. For each pair of terms T_{EX} (from the expanded term set) and T_C (from the concept term set), perform the geospatial data discovery process by repeating the following steps:

- Compute edit distance similarity for terms T_{EX} and T_C

  Edit distance similarity is measured according to Levenshtein distance [52] and is given by $dist(length(T_{EX}), length(T_C))$ whereas the formula used to calculate $dist(length(T_{EX}), length(T_C))$ is given by the following equation:

$$dist_{T_{EX},T_C}(i_{T_{EX}}, j_{T_C}) = \begin{cases} Max(i_{T_{EX}}, j_{T_C}), when \rightarrow Min(i_{T_{EX}}, j_{T_C}) = 0 \\ Min\begin{cases} dist_{T_{EX},T_C}(i_{T_{EX}} - 1, j_{T_C}) + 1 \\ dist_{T_{EX},T_C}(i_{T_{EX}}, j_{T_C} - 1) + 1 \\ dist_{T_{EX},T_C}(i_{T_{EX}} - 1, j_{T_C} - 1) + (T_{EX}[i_{T_{EX}}] = T_C[j_{T_C} - 1] ? 0 : 1) \end{cases}, when \rightarrow Min(i_{T_{EX}}, j_{T_C}) \end{cases} \quad (1)$$

- Compute semantic similarity $sim(T_{EX}, T_C)$, according to equation 2, between the terms T_{EX} and T_C according to the algorithm described in [53]. According to this algorithm, $sim(T_{EX}, T_C)$ is determined by considering the depths of the T_{EX} and T_C synsets in the WordNet computational lexicon, along with the depth of their least common subsumer (LCS). The LCS of synsets T_{EX} and T_C is the most specific synset that is an ancestor of both synset T_{EX} and T_C.

$$sim(T_{EX}, T_C) = \frac{2 * depth(LCS_{T_{EX},T_C})}{depth(T_{EX}) + depth(T_C)} \quad (2)$$

- Determine final semantic similarity according to the equation 3:

$$semsim(T_{EX}, T_C) = Max(dist(length(T_{EX}), length(T_C)), sim(T_{EX}, T_C)) \quad (3)$$

After a matching set of ontology concepts is calculated, CPS will utilize GeoNis semantic mediator to determine OGC Web services (WMS and WFS instances) used as interfaces of geo-information sources connected to ontology concepts from the matched set. This process uses existing connections (mappings) between global ontology and geo-information sources within GeoNis interoperability platform. Once OGC Web services instances are determined, a set of layer names and/or feature type names is sent back to WMCS for context document creation purposes in the form of an argument of *GetLayers* operation of WMCS service.

Based on the received term set, *GetLayers* operation of WMCS service will create a temporary contextual document and apply appropriate ordering of results. For example, if a match is found among the keywords used in one or more of the existing contextual documents, WMCS adds all data layers from each of the contextual documents into the resulting set of data layers. For this reason, a preference in result ordering is given to data layer name matches.

4. Use Case

In a local community environment, one of the largest geodata producers and users are public utility companies and the local government. As it turned out to be, each of the public utility companies, along with local government departments, has its own set of geodata but can also benefit from the usage of geodata sets owned by another public institution or company. The number of geospatial data consumers is increasing with the expansion of useful geospatial data within a local community environment. These influences introduce a necessity for the development of geoprocessing tools capable of integrating geospatial data from distributed information sources and visualizing integrated data according to user needs. Being such, this situation introduces a need for a GIS solution that will be user focused and at the same time will allow for each of the companies and institutions to maintain their own unique branding within the GIS solution through which their content is available.

The tool which can be used in the described situation is a Web GIS capable of dealing with the problems of visualization and interpretation of integrated geospatial information as problems related to the special architectural layer of the Web GI system. This layer of the Web GI system should functionally perform visualization of integrated information according to user preferences in a way which will allow easier interpretation of the visualized data and easier decision making based on this interpretation. We consider WMCS and CPS to be the fundamental components for the fulfillment of the designated requirements.

For the feasibility testing purposes, we have simulated a situation where two different users in a local community environment are using the architecture and the infrastructure defined in this paper: local government officer and public electric supply company employee. Each of users will define a natural language description of geo-information according to its interest. According to the first step of the previously described geospatial data source discovery process, a natural language descriptions of geo-information are utilized to extract the input term sets for each of users. Each natural language description of geo-information is tokenized into a list of words. For these purposes, regular expressions were used. Afterwards, WordNet computational lexicon is utilized to identify the correct part of speech (noun, verb, pronoun or adverb) for each of the words. At this stage, geospatial data source discovery process is restricted to utilizing only extracted nouns whereas extracted nouns are coupled in cases there is no word between them in the original natural language description of geo-information. In this use case, the following input term sets were extracted:

- local government officer input term set: streets, house numbers, urban plan, feeders, map.
- public electric supply company employee input term set: substations, feeders, poles, consumers, streets, house numbers, map.

These input term sets are used for geospatial data source discovery process described in the previous section. Once the discovery process is finished, CPS will utilize GeoNis semantic mediator to determine OGC Web service used as interfaces of discovered geo-information sources. Afterwards, CPS will acquire a set of layer names and/or feature type names for each of the discovered OGC Web services and send them back to WMCS for context document creation purposes.

Based on the received set of layer names and/or feature type names, WMCS creates a temporary context document which contains all suggested layers names and/or feature type names. This document is sent back to users which have the ability to choose the data they are interested in among the discovered geospatial data. Once users choose the appropriate geospatial data (grouped within layers and/or feature types) Web GIS client sends RegisterContext request including all chosen parameters in order to register user’s context documents. One possible user’s choice of data, chosen among the discovered geospatial data, is shown on Figures 4, 5, 6 and 7. Each user choice is used to generate user’s context document which is in turn used within the Web Map solution.

This case study shows the ability of the presented architecture and services (WMCS and CPS) to generate different maps for different users with the same data according to defined context documents. The presented case study demonstrates the possible use of the architecture and services for establishing different Web Map solutions on top of a unique spatial data infrastructure developed according to OGC specifications.

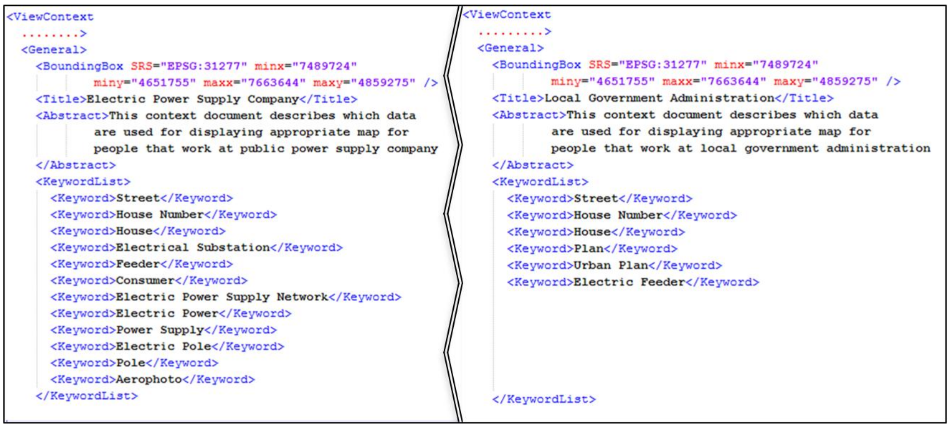

Fig. 4. A comparison of context documents for two users – a comparison of keyword lists

```xml
<Layer queryable="0" hidden="0">
<Server service="OGC:WMS" version="1.1.0" title="Web Map Service">
  <OnlineResource xlink:type="simple" xlink:href="http://160.99.9.100:8080/wms" />
</Server>
<Name>electrical_substations</Name>
<Title>Electrical Substations</Title>
<SRS>EPSG:31277</SRS>
<FormatList>
  <Format current="1">text/xml</Format>
</FormatList>
<StyleList>
  <Style current="1">
    <Name>es_blue</Name>
    <Title>Blue es color</Title>
    <Abstract>Use this style to display all electrical substations with blue color</Abstract>
    <SLD>
      <Name>esblue</Name>
      <OnlineResource xlink:type="simple" xlink:href="http:/160.99.9.101:8080/ser" />
    </SLD>
  </Style>
</StyleList>
</Layer>
<Layer queryable="0" hidden="0">
<Server service="OGC:WMS" version="1.1.0" title="Web Map Service">
  <OnlineResource xlink:type="simple" xlink:href="http://160.99.9.100:8080/wms" />
</Server>
<Name>poles</Name>
<Title>Poles</Title>
<SRS>EPSG:31277</SRS>
<FormatList>
  <Format current="1">text/xml</Format>
</FormatList>
<StyleList>
  <Style current="1">
    <Name>pole_blue</Name>
    <Title>Blue pole color</Title>
    <Abstract>Use this style to display all poles with blue color</Abstract>
    <SLD>
      <Name>poleblue</Name>
      <OnlineResource xlink:type="simple" xlink:href="http:/160.99.9.101:8080/ser" />
    </SLD>
  </Style>
</StyleList>
</Layer>
```


Fig. 5. A comparison of context documents for two users – different WFS feature types

For the scenario represented on Figures 4, 5, 6 and 7, registered context documents differ in the following:

- Registered context documents have different context IDs which are used as titles of context documents. The two contexts share some of the keywords used for their description, such as streets, house number and feeders. On the other hand, keyword lists used for the description of these contexts differ in keywords related to the scope of the context, as shown in Figure 4.
- The public electric supply company employee's context document has four layers which are used to display geospatial data about public electric supply network, as shown in Figure 5. In order to display simple electric supply network in combination with local government geospatial data, the local government officer has chosen feeder layer from the electric supply network service (Figure 9).
- In these context documents, two layers are the same: streets and house number (Figure 6). These layers are displayed in different ways on the resulting maps because of different styles which were assigned to these layers in context documents. For the current work of local government officer, layer of geospatial data which present an urban plan are very important and this layer is included in the user context document and shown in the resulting map, as shown in Figures 7 and 9.

- For the better visualization of layers related to different user's needs, users have chosen different raster maps – aerophoto (local government officer) and cadastre plan (public electric supply company employee), as shown on Figures 7, 8 and 9.

```xml
<Layer queryable="0" hidden="0">
<Server service="OGC:WFS" version="1.1.0" title="Web Feature Service">
  <OnlineResource xlink:type="simple"
        xlink:href="http://160.99.9.102:8080/wfs" />
</Server>
<Name>streets</Name>
<Title>Streets</Title>
<SRS>EPSG:31277</SRS>
<FormatList>
  <Format current="1">text/xml</Format>
</FormatList>
<StyleList>
  <Style current="1">
    <Name>street_gray</Name>
    <Title>Gray street color</Title>
    <Abstract>Use this style to display all streets with
        gray color  </Abstract>
    <SLD>
      <Name>strgray</Name>
      <OnlineResource xlink:type="simple"
          xlink:href="http:/160.99.9.101:8080/ser" />
    </SLD>
  </Style>
</StyleList>
</Layer>
<Layer queryable="0" hidden="0">
<Server service="OGC:WFS" version="1.1.0" title="Web Feature Service">
  <OnlineResource xlink:type="simple"
        xlink:href="http://160.99.9.102:8080/wfs" />
</Server>
<Name>house_numbers</Name>
<Title>House Numbers</Title>
<SRS>EPSG:31277</SRS>
<FormatList>
  <Format current="1">text/xml</Format>
</FormatList>
<StyleList>
  <Style current="1">
    <Name>hn_gray</Name>
    <Title>Gray house number color</Title>
    <Abstract>Use this style to display all house numbers
            with gray color</Abstract>
    <SLD>
      <Name>hbgray</Name>
      <OnlineResource xlink:type="simple"
          xlink:href="http://160.99.9.101:8080/ser" />
    </SLD>
  </Style>
</StyleList>
</Layer>
```

```xml
<Layer queryable="0" hidden="0">
<Server service="OGC:WFS" version="1.1.0" title="Web Feature Service">
  <OnlineResource xlink:type="simple"
        xlink:href="http://160.99.9.102:8080/wfs" />
</Server>
<Name>streets</Name>
<Title>Streets</Title>
<SRS>EPSG:31277</SRS>
<FormatList>
  <Format current="1">text/xml</Format>
</FormatList>
<StyleList>
  <Style current="1">
    <Name>street_blue</Name>
    <Title>Blue street color</Title>
    <Abstract>Use this style to display all streets
        with blue color</Abstract>
    <SLD>
      <Name>strblue</Name>
      <OnlineResource xlink:type="simple"
          xlink:href="http:/160.99.9.101:8080/ser" />
    </SLD>
  </Style>
</StyleList>
</Layer>
<Layer queryable="0" hidden="0">
<Server service="OGC:WFS" version="1.1.0" title="Web Feature Service">
  <OnlineResource xlink:type="simple"
        xlink:href="http://160.99.9.102:8080/wfs" />
</Server>
<Name>house_numbers</Name>
<Title>House Numbers</Title>
<SRS>EPSG:31277</SRS>
<FormatList>
  <Format current="1">text/xml</Format>
</FormatList>
<StyleList>
  <Style current="1">
    <Name>hn_blue</Name>
    <Title>Blue house number color</Title>
    <Abstract>Use this style to display all house
          numbers with blue color</Abstract>
    <SLD>
      <Name>hblue</Name>
      <OnlineResource xlink:type="simple"
          xlink:href="http://160.99.9.101:8080/ser" />
    </SLD>
  </Style>
</StyleList>
</Layer>
```

Fig. 6. A comparison of context documents for two users – similar WFS feature types

```xml
<Layer queryable="0" hidden="0">
  <Server service="OGC:WMS" version="1.1.0" title="Web Map Service">
    <OnlineResource xlink:type="simple" xlink:href="http://160.99.9.102:8080/wms" />
  </Server>
  <Name>aerofoto</Name>
  <Title>Aerophoto</Title>
  <SRS>EPSG:31277</SRS>
  <FormatList>
    <Format current="1">image/png</Format>
    <Format>image/bmp</Format>
    <Format>image/gif</Format>
    <Format>image/jpeg</Format>
  </FormatList>
</Layer>
```

```xml
<Layer queryable="0" hidden="0">
  <Server service="OGC:WMS" version="1.1.0" title="Web Map Service">
    <OnlineResource xlink:type="simple" xlink:href="http://160.99.9.102:8080/wms" />
  </Server>
  <Name>urban_plan</Name>
  <Title>Urban Plan</Title>
  <SRS>EPSG:31277</SRS>
  <FormatList>
    <Format current="1">image/png</Format>
    <Format>image/bmp</Format>
    <Format>image/gif</Format>
    <Format>image/jpeg</Format>
  </FormatList>
</Layer>
<Layer queryable="0" hidden="0">
  <Server service="OGC:WMS" version="1.1.0" title="Web Map Service">
    <OnlineResource xlink:type="simple" xlink:href="http://160.99.9.102:8080/wms" />
  </Server>
  <Name>aerofoto</Name>
  <Title>Aerophoto</Title>
  <SRS>EPSG:31277</SRS>
  <FormatList>
    <Format current="1">image/png</Format>
    <Format>image/bmp</Format>
    <Format>image/gif</Format>
    <Format>image/jpeg</Format>
  </FormatList>
</Layer>
```

Fig. 7. A comparison of context documents for two users – a comparison of WMS layers

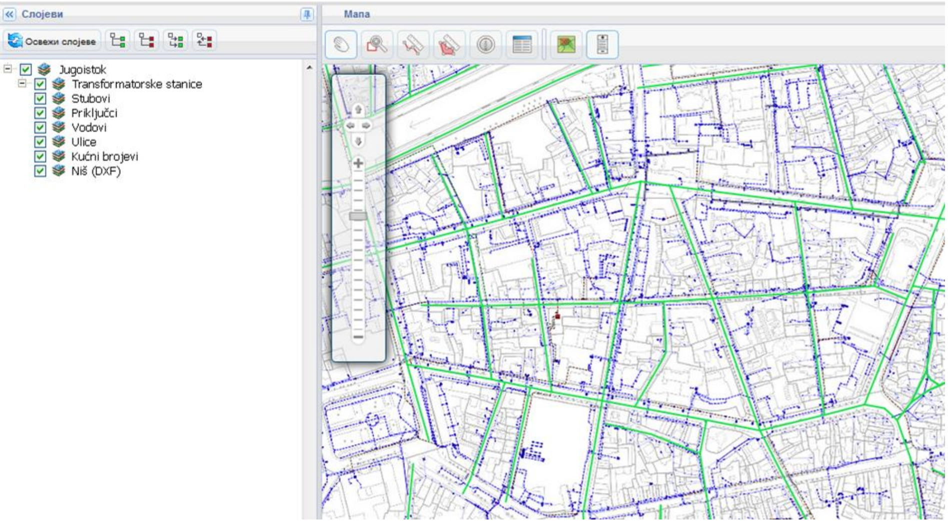

Fig.8. Web GIS client appearance for public electric supply company employee

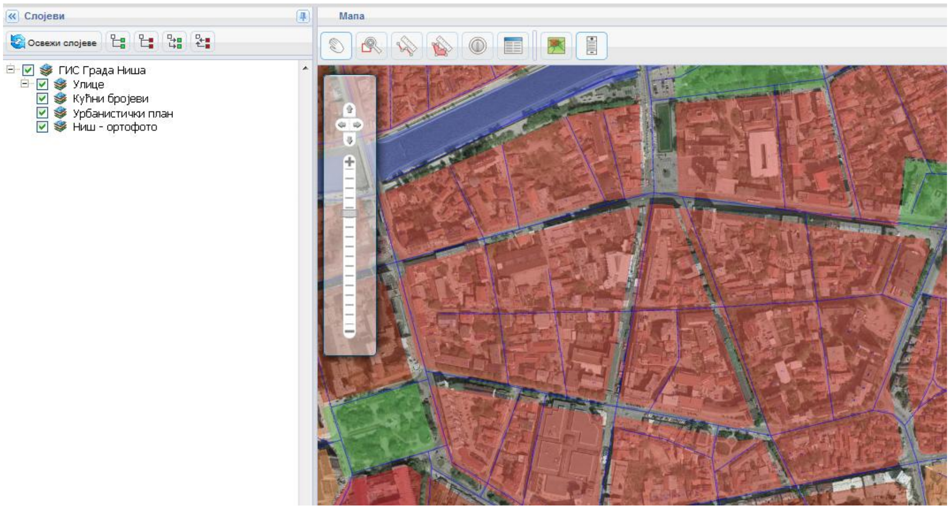

Fig.9. Web GIS client appearance for local government officer

5. Evaluation of WMCS characteristics

Currently, there is a limited number of prominent proposals that can be considered similar to WMCS to some extent. After evaluating these proposals, it is our conclusion that not many of them cover all functionalities specified and implemented within WMCS. A comparison of these proposals is given in Table 1.

Table 1. A comparison of context-driven Web Map solutions

	Reichenbacher	**GiMoDig**	**Sissi**	**OGC WCPS**	**OGC CS**	**WMCS**
Architecture	Client-Server	Client-Server	Client-Server	Web Service	Web Service	Web Service
Context types	Predefined	Invariant	User-defined	-	-	User-defined
Context document format	Internal format	Internal format used for visualization generalization	Array of strings, comma-separated values	-	-	OGC Web Map Context Documents
Supported OGC Web Services	WFS	WMS, WFS	WMS	-	WMS, WFS, WCS...	WMS, WFS
Styling language	SVG	SVG	SLD	-	-	SLD, SE
The position of symbology	Uses a separate visualization adaptation process named Adapmap (based on CSS and XSLT)	Integral part, a functionality of Map Adaptation Service	Integral part	-	-	Based on the usage of style repositories
Based on OGC standards?	No	Yes	Yes	Yes	Yes	Yes
Is the solution an extension of an existing standard?	No	No	Yes	No	No	No
Includes metadata catalogue or mediator component?	No	No	No	No	Yes	Yes

As we previously stated, we consider Contextual Map Service named Sissi to be the most similar solution compared to our proposal. However, WMCS differs from Sissi in more than few characteristics in terms of both surrounding architecture and specified functionalities. Although Sissi does not have a predefined set of elementary context types, a variety of user context types could be more efficiently covered if the user context is stored as a separate document and developed according to Web Map Context Documents specification. This capability is supported by WMCS. Unlike Sissi, WMCS does not perform any rendering in terms of merging images from different Web Map Services. Rather, WMCS uses the rendering capabilities of the existing Web Map Service rendering, therefore does not multiply requests towards the existing Web Map Services. This characteristic can be significant in terms of performances of the overall system. Furthermore, the usage of WFS services is not provisioned in the Sissi environment. The direct usage of WFS services can be very significant if clients are capable of adapting geospatial data presentation according to the style provided on the basis of the user context. Also, it is our opinion that the used symbology should not be restricted to SLD. Furthermore, styling rules can be provided by independent services, possibly in the form of styling document repositories [54]. These capabilities are also integrated into Web Map Context Service specification.

6. Conclusion and Outlook to Future Work

In this paper, our objective was to define and develop a general architecture of context-driven Web Map solutions which will improve the level of usability of contextual geospatial information visualization systems. The main result within this research and development is the ability of our proposal to apply different contexts and styles for viewing maps. This is achieved by introducing an additional architectural layer into the Web-based GIS application interoperability platforms. This layer consists of Web GIServices capable of supporting contextual geospatial visualization and we envision Web Map Context Service as its most important component.

The architecture presented in this paper should be considered an excellent starting point for the development of service oriented GIS capable of supporting contextual cartographic visualization. Future research and development of the presented service and its environment should involve an extension of WMCS specification in terms of new operations based on Web Processing Service OGC Standard (WPS). Such extension will provide WMCS with the ability to use Context Proposal Services (CPS) developed by a third-party. Currently, coupled with our implementation of Context Proposal Services, WMCS enables users to be introduced with the already-existing similar contexts which lead to a faster adaptation of geospatial data visualization and improve reusability of the existing symbology. Once extended according to WPS standard, WMCS will be able to use CPSs developed for a particular domain which can be very significant for users which consider themselves experts for the observed domain.

Further, the WMCS specification will be extended with operations which will allow users to register style transformation scripts. Registered scripts will perform transformation between a custom styling document and a styling document developed according to OGC specification. Thus, WMCS will be able to transform styling documents developed according to third-party styling languages into styling documents developed according to OGC specification. Each styling language developer will use WMCS operations in order to register a XSLT [55] or a procedural transformation of its styling language into SLD or SE styling language. We are convinced that these improvements will lead to our proposal becoming a solution highly applicable within any existing geospatial data visualization environment and its usage will turn such environment into an adaptive geospatial data visualization environment.

References

1. de la Beaujardiere, J. (ed.): OpenGIS Web Map Server Implementation Specification, v1.3.0. OGC 06-042. Open Geospatial Consortium, Inc., 85pp. (2006) http://portal.opengeospatial.org/files/?artifact_id=14416
2. Vretanos, P. A. (ed.): Web Feature Service Implementation Specification v1.1.0. OGC 04-094, Open Geospatial Consortium, Inc., 131pp., (2005) http://portal.opengeospatial.org/files/?artifact_id=8339
3. Open Geospatial Consortium, Evans, J.D. (ed.), Web Coverage Service (WCS) Implementation Specification (Corrigendum) v1.1.0. OGC 05-076, 67pp. (2005) https://portal.opengeospatial.org/modules/admin/license_agreement.php?suppressHeaders=0&access_license_id=3&target=http://portal.opengeospatial.org/files/?artifact_id=12582
4. Open Geospatial Consortium, Schut P. (ed.), OpenGIS Web Processing Service, v1.0.0, OGC 05-007r7, 87pp. (2007) https://portal.opengeospatial.org/modules/admin/license_agreement.php?suppressHeaders=0&access_license_id=3&target=http://portal.opengeospatial.org/files/%3fartifact_id=24151
5. Meditskos, G., Bassiliades, N.: A combinatory framework of Web 2.0 mashup tools, OWL-S and UDDI, Expert Systems with Applications, 38, pp. 6657–6668, (2011)
6. Stock K. M., Atkinson R., Higgins C., Small M., Woolf A., Millard K.: A semantic registry using a Feature Type Catalogue instead of ontologies to support spatial data infrastructures, International Journal of Geographical Information Science, 24, pp. 231–252 (2010)
7. Open Geospatial Consortium, Maue P. (ed.): Semantic annotations in OGC standards, OGC 08-167r1, Version: 0.3.0, (2009) https://portal.opengeospatial.org/modules/admin/license_agreement.php?suppressHeaders=0&access_license_id=3&target=http://portal.opengeospatial.org/files/%3fartifact_id=34916
8. Buccella, A., Cechich, A., Fillottrani, P.: Ontology-driven geographic information integration: A survey of current approaches. Computers & Geosciences, 35 (4), (2009)
9. Hakimpour, F.: Using ontologies to resolve semantic heterogeneity for integrating spatial database schemata. Ph.D. Dissertation, Zurich University, Switzerland, 191pp. (2003)
10. Tellez-Arenas, A.: Best Practice Report on Geoportals, ECP-2007-GEO-317001, OneGeology-Europe, (2009)
11. Kuhn, W.: Semantic reference systems, International Journal of Geographical Information Science, 17, pp. 405–409 (2003)
12. Tian Y., Huang M.: Enhance discovery and retrieval of geospatial data using SOA and Semantic Web technologies, Expert Systems with Applications, Vol. 39 (16), pp. 12522–12535, Elsevier Ltd, (2012)
13. Stoimenov, L., Đorđević-Kajan, S.: Framework for Semantic GIS Interoperability, FACTA Universitatis, Series Mathematics and Informatics, Vol.17, 2002, pp.107-125, (2002)
14. Stoimenov, L., Đorđević-Kajan, S.: An architecture for interoperable GIS use in a local community environment, Computers &Geosicence, Elsevier,.31, 211-220, (2005)
15. Wache, H., Vogele, T., Visser, U., Stuckenschmidt, H., Schuster, G., Neumann, H., Hubner, S.: Ontology-based integration of information—a survey of existing approaches. In IJCAI-01 Workshop: Ontologies and Information Sharing, Seattle, USA, 108–117, (2001)
16. Stanimirović, A., Bogdanović, M., Stoimenov, L.: Methodology and intermediate layer for the automatic creation of ontology instances stored in relational databases, Software: Practice and Experience, (2012), DOI: 10.1002/spe.2103
17. Petit, M., Ray, C., Claramunt, C.: A User Context Approach for Adaptive and Distributed GIS. In: Proceedings of the 10th International Conference on Geographic Information Science (AGILE'07), March. Aalborg, Denmark: Springer-Verlag, LN series on Geoinformation and Cartography, pp. 121-133, (2007)
18. Petit, M., Ray, C., Claramunt, C.: A contextual approach for the development of GIS: Application to maritime navigation. In J. Carswell and T. Tekuza, editors, Proceedings of the

6th International Symposium on Web and Wireless Geographical Information Systems, number 4295 in LNCS, pages 158–169. Springer-Verlag, (2006)

19. Yang, Y., Claramunt, C.: A hybrid approach for spatial web personalisation. In C. Vangenot and K. Li, editors, Proceedings of the 5th international workshop on Web and Wireless Geographical Information Systems, number 3833 in LNCS,pages 206–221. Springer-Verlag, (2005)
20. Cullot, N., Ghawi, R., Yetongnon, K., DB2OWL: a tool for automatic database-to-ontology mapping. Proceedings of 15th Italian Symposium on Advanced Database Systems (SEBD 2007), Fasano, Brindisi, Italy, 491–494, (2007)
21. Baglioni, M., Masserotti, M. V., Renso, C., Spinsanti, L.: Building geospatial ontologies from geographical databases. In Lecture Notes in Computer Science: Proceedings of The Second International Conference on GeoSpatial Semantics (GeoS 2007), Vol. 4853. Springer: Berlin/Heidelberg, 195–209, (2007), DOI: 10.1007/978-3-540-76876-0_13.
22. Euzenat, J., Shvaiko, P.: Ontology Matching. Springer, Berlin, Heidelberg, DE, 341pp. (2007)
23. Meditskos G., Bassiliades N.: Structural and role-oriented web service discovery with taxonomies in OWL-S, Ieee Transactions on Knowledge and Data Engineering, 22, pp. 278–290 (2010)
24. Martin D., Paolucci M., McIlraith S., Burstein M., McDermott D., McGuinness D.: Bringing semantics to web services the OWL-S approach, J. Cardoso, A. Sheth (Eds.), SWSWPC 2004, Vol. 3387 Springer, pp. 26–42, (2004)
25. Lutz M., Sprado J., Klien E., Schubert C., Christ I.: Overcoming semantic heterogeneity in spatial data infrastructures, Computers & Geosciences, 35, pp. 739–752, (2009)
26. Cabral, L., Domingue, J., Motta, E., Payne, T., Hakimpour, F., Approaches to semantic web services: an overview and comparisons. In C. Bussler, J. Davies, D. Fensel & R. Studer (Eds.), Lecture Notes in Computer Science (LNCS3053) (Vol. 3053, pp. 225–239) (2004)
27. Lupp, M. (Ed.): Styled Layer Descriptor Profile of the Web Map Service Implementation Specification, v1.1.0.OGC 05-078r4. Open Geospatial Consortium, Inc., 53pp. (2007) http://portal.open-geospatial.org/files/?artifact_id=22364
28. Klien, E., Fitzner, D., Maué, P.: Baseline for registering and annotating geodata in a semantic web service framework. In 10th AGILE international conference on geographic information science, Aalborg, Denmark (2007)
29. de Bruijn J., Fensel D., Keller U., Lara R.: Using the Web Service modeling ontology to enable semantic e-business, Communications of the ACM, 48, pp. 43–47 (2005)
30. Open Geospatial Consortium, Perry, M. & Herring, J. (Eds.): OGC GeoSPARQL - A Geographic Query Language for RDF Data, v1.0, OGC 11-052r4, 75pp. (2012) https://portal.opengeospatial.org/files/?artifact_id=47664
31. Lieberman, J., Reich, L., Vretanos, P.: OWS1.2 UDDI Experiment, Version 0.5, OpenGIS Interoperability Program Report, OGC 02–054r1 (2003)
32. Goodwin J. C., Russomanno D. J., Qualls J.: Survey of Semantic Extensions to UDDI: Implications for Sensor Services, in: H.R. Arabnia (Ed.), the 2007 International Conference on Semantic Web & Web Services, SWWS 2007, CSREA Press, Las Vegas, Nevada, USA, pp. 16–22 (2007)
33. Herzog, R., Lausen, H., Roman, D., Zugmann, P.: D10 v0.1 WSMO Registry, WSMO Working Draft 26 April 2004. http://www.wsmo.org/2004/d10/v0.1/ (2004)
34. Gruber, T., A translation approach to portable ontology specifications. Knowledge Acquisition 5 (2), 199–220 (1993)
35. Fonseca F.T., Egenhofer M.J.: Ontology-driven geographic information systems. Proceedings of the 7th ACM International Symposium on Advances in Geographic Information Systems, Kansas City, Missouri, U.S.A.; 14–19. (1999)

36. W3C RDB2RDF Incubator Group: A Survey of Current Approaches for Mapping of Relational Databases to RDF, (2009) http://www.w3.org/2005/Incubator/rdb2rdf/RDB2RDF_SurveyReport.pdf
37. Malhotra, A. (Ed.): W3C RDB2RDF Incubator Group Report. (2009) http://www.w3.org/2005/Incubator/rdb2rdf/XGR-rdb2rdf-20090126/
38. Auer S., Dietzold S., Lehmann J., Hellmann S., Aumueller D.: Triplify – Light-Weight Linked Data Publication from Relational Databases. In: Proceedings of the 18th World Wide Web Conference (WWW2009), New York, USA (2009)
39. W3C RDB2RDF Working Group, RDB2RDF, (2012) http://www.w3.org/2001/sw/wiki/RDB2RDF
40. Shearin, S., Lieberman, H.: Intelligent profiling by example. In Proceedings of the International Conference on Intelligent User Interfaces, pages 145–152. ACM Press, (2001)
41. Hampe, M., Paelke, V.: Adaptive maps for mobile applications. In Proceedings of the Mobile Maps Workshop at MobileHCI'05, (2005)
42. Reichenbacher, T.: Adaptive methods for mobile cartography. In Proceedings of the 21st International Cartographic Conference, pp. 1311–1322, (2003)
43. Zipf, A.: Using Styled Layer Descriptor (SLD) for the dynamic generation of user- and context-adaptive mobile maps – a technical framework, 5th International Workshop on Web and Wireless Geographical Information Systems (W2GIS), Lausanne, Switzerland, (2005)
44. Reichenbacher, T.: Mobile Cartography-Adaptive Visualisation of Geographic Information on Mobile Devices. Ph.D. Dissertation, Institute of Photogrammetry und Cartography, Technical University, Munich, Germany, 198pp., (2004)
45. Sarjakoski, T., Sester, M., Sarjakoski, L. T., Harrie, L., Hampe, M., Lehto, L., Koivula T.: Web generalisation services in GiMoDig – Towards a standardised service for real-time generalisation, in Proceedings of 8th AGILE International Conference on Geographic Information Science 2005, Estoril, Portugal, 26.-28. May, pp. 509-518, ISBN: 972-8093-13-6, (2005) http://plone.itc.nl/agile_old/Conference/estoril/themes.htm
46. Kozel, J., Stampach, R.: Practical Experience with Contextual Map Service. In M. Konecny, S. Zlatanova, T. Bandrova: Geographic Information and Cartography for Risk and Crisis Management. London : Springer. ISBN: 978-3-642-03441-1, (2010)
47. Lupp, M. (Ed.): Styled Layer Descriptor Profile of the Web Map Service Implementation Specification, v1.1.0.OGC 05-078r4. Open Geospatial Consortium, Inc., 53pp. (2007) http://portal.open-geospatial.org/files/?artifact_id=22364
48. Stoimenov, L., Stanimirović A., Đorđević-Kajan, S.: Realization of Component-Based GIS Application Framework, Proceedings printed as book, Eds. F.Toppen, P.Prastacos, 7th AGILE Conference on Geographic Information Science, AGILE 2004, Heraklion, Crete, Greece, April 29 – May 1, 2004., ISBN 960-524-176-5, 2004, Crete University Press, pp.113-120, (2004)
49. Müller, M. (Ed.): Symbology Encoding Implementation Specification, v1.1.0. OGC 05-077r4, Open Geospatial Consortium, Inc., 63pp. (2006) http://portal.open-geospatial.org/files/?artifact_id=16700
50. Sonnet, J. (Ed.) : Web Map Context Documents v1.1.0. OGC 05-005, 30pp., (2005) https://portal.opengeospatial.org/modules/admin/license_agreement.php?suppressHeaders=0&access_license_id=3&target=http://portal.opengeospatial.org/files/%3fartifact_id=8618
51. Whiteside, A., Greenwood, J. (Eds.): OGC Web Service Common Standard, v2.0.0. OGC 06-121r9, Open Geospatial Consortium, Inc., 207pp., (2010) http://portal.open-geospatial.org/files/?artifact_id=38867
52. Levenshtein, V.: Binary codes capable of correcting deletions, insertions and reversals. Soviet Physics-Doklady, Vol. 10, No. 8, 707–710. Original in Russian in Dokl.Akad.Nauk SSSR 163, 4, 845–848, (1965)

53. Wu, Z., Palmer, M. S.: Verb Semantics and Lexical Selection.Proceedings of the 32th Annual Meeting on Association for Computational Linguistics, (pp. 133-138) Las Cruces, New Mexico, (1994)
54. Bogdanović, M., Vulović, D., Stoimenov, L.: Symbology Encoding Repository, in Proceedings of 13th AGILE International Conference on Geographic Information Science 2010, Guimaraes, Portugal, 10.-14. May (2010) ISBN: 978-989-20-1953-6, http://agile2010.dsi.uminho.pt
55. Clark, J. (Ed.): XSL Transformations (XSLT) v1.0., World Wide Web Consortium (W3C), 1999, http://www.w3.org/TR/1999/REC-xslt-19991116
56. Kale, U. D., Lad, R.: GIS integration with SCADA, DMS & AMR in Electrical Utility, Map India Conference (2006)
57. Bogdanovic, M., Stanimirovic, A., Davidovic, N., Stoimenov, L.: Web-based GIS Solution for Electric Power Supply Network Data Management. In Proceeding of 12th AGILE International Conference on Geographic Information Science, Hannover, Germany (2009)
58. Fellbaum, C.: WordNet: An Electronic Lexical Database (Language, Speech, and Communication), The MIT Press (1998)

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Received: October 31, 2014; Accepted: April 14, 2015.