Web Map Context Service for Adaptive Geospatial Data Visualization

Miloš Bogdanović, Danilo Vulović, Leonid Stoimenov

Faculty of Electronic Engineering, University of Niš, Serbia
{milos.bogdanovic, leonid.stoimenov, danilo.vulovic}@elfak.ni.ac.rs

INTRODUCTION

Since the emergence of GIS tools, there has been an increase of spatial data usage throughout the world. The increase of spatial data dissemination is facilitated by the development of communication technology, e.g. the development of the Internet. Nowadays, a majority of data transfer is accomplished through the Internet. Spatial data can be accessed through standardized Web Services which sometimes offer large quantities of spatial data. Since the transfer of large quantities of data can be time consuming, spatial data sets need to be efficiently and appropriately reduced. Inappropriate spatial data set reduction can lead to inappropriate presentation of the transferred data. From the perspective of geovisualization tool user, this can affect the usability of any geovisualization tool that uses gathered spatial data. When considering these tools, the representation of geographic features and maps is essential for easier understanding of depicted data and processes. Therefore, appropriate spatial data presentation should be preserved on a user level.

The ability to control detailed graphical representation of geographic objects can be highly important to GIS users. The control of graphical representation is usually accomplished by defining styles that will be used to display the group or individual geographic objects and maps. GIS applications that take advantage of user-defined styles become capable of embedding the meaning of the displayed object through its graphical representation. Different styles used for geospatial data representation are created according to user needs and demands.

Unlike traditional GIS, contemporary (desktop, Web, mobile) GIS is able to use maps created for a single user or a particular situation according to user-defined geospatial data presentation styles. Contemporary GIS uses user-defined styles in order to enable geospatial data representation to be created on user demand. In this way, GIS becomes able to dynamically adapt map content according to preferred user style, e.g. able to perform adaptive geospatial data visualization. The input for this kind of geospatial data visualization should be a description of the situation and objects that presentation style corresponds to. This type of a description usually consists of information that should affect application running and appearance and is referred to as context (Kozel, 2007).

Contextual information enables users to indirectly affect geospatial data appearance. Contemporary GIS should receive contextual information, determine user context according to contextual information and perform the adaptation of geospatial data representation. According to Open Geospatial Consortium (OGC) standards, this process is effectively delegated to multiple Web services. As a consequence, a retrieval of the contextual information and a determination of the user context are often implemented as functions of a separate Web service (Sarjakoski et al., 2005). This service is used as a proxy between users and geospatial data visualization services and is responsible for selecting an appropriate symbology.

The aim of this paper is to present a specification of a context service used for adaptive geospatial data visualization and an architecture surrounding it. With respect to all previous implementations, we will make use of reported experiences with contextual services and make a step forward in terms of service specification and environment architecture. Our proposal is specified in accordance with OGC Web Service Common Standard (Open Geospatial Consortium, 2010) and is capable of using distributed geospatial data style repositories (Bogdanović et al., 2010) in combination with user contexts. User contexts used by our service are developed according to Web Map Context Documents implementation specification. After presenting its specification and operating environment, this service will prove to be capable of supporting the adoption of geospatial data representation on both server (such as Web Map Service) and client (desktop, Web, mobile GIS) side.

RELATED WORK

In the process of Geo-Information System (GIS) development the importance of visual identification of geospatial data can not be ignored (Open Geospatial Consortium, 2007a) (Open Geospatial Consortium, 2006). Significant effort has been made towards developing styles used for visualization of geographic objects and maps. As a result, different styling languages and catalogues of styles have been proposed. OGC proposed Geography Markup Language (GML) (Open Geospatial Consortium, 2007b) which was combined with Scalable Vector Graphics (SVG) (World Wide Web Consortium, 2009) and XSL Transformation (World Wide Web Consortium, 1999) for the purpose of geospatial data visualization, mostly within Web GIS clients (Mathiak et al., 2004) (Tennakoon, 2003). Styled Layer Descriptor (SLD) (Open Geospatial Consortium, 2007a) and Symbology Encoding (SE) (Open Geospatial Consortium, 2006) styling language specifications have also been proposed by OGC. Aside from languages coupled with specific systems, such as Cartographic Markup Language (CartoML) (Baer, 2003) and Diagram Markup Language (DiaML) (Schnabel and Hurni, 2007), OGC SLD and SE have been broadly accepted and used. Recent research has shown that usage of these styling languages, in combination with information regarding GIS user context, can highly improve usability of GIS (Reichenbacher, 2004) (Sarjakoski et al., 2005) (Kozel and Stampach, 2010). This is one of the reasons why an effort has been made in order to make GIS able to adopt geospatial data visualization according to user needs, e.g. towards performing adaptive (contextual) cartographic visualization (Reichenbacher, 2004) (Sarjakoski et al., 2005) (Kozel and Stampach, 2010).

A majority of solutions that support adaptive (contextual) cartographic visualization is based on client–server architecture. (Reichenbacher, 2004) proposed a solution for adaptive visualization of geospatial information on mobile devices. Partially because of the limitations that this environment introduces, adaptive cartographic visualization was performed on the server side while client side was only responsible for presentation of geospatial data. This solution uses a set of predefined context types. Similar solution can be found in GiMoDig project (Sarjakoski et al., 2005), which is also based on client-server architecture. GiMoDig architecture introduces extensions of WMS and WFS specification used for the purpose of establishing communication between server and client side. Context types used in this architecture are invariant.

Probably the most similar solution to one presented in this paper and one of the best implementation we encountered is named Sissi – Contextual Map Service. This solution was designed in 2007 (Kozel and Stampach, 2010). Sissi is also based on client-server architecture. However, compared to previously described solutions, Sissi differs in more that few characteristics which are, in our opinion, very significant. Unlike mentioned solutions, Sissi does not have a predefined set of elementary context types. Therefore, it is capable of supporting different contexts. Its specification is based on WMS specification with extending requests – *GetElementaryContextType* and *GetMapWindows*. Also, WMS *GetCapabilities* request has been modified in order to include additional *context* parameter. *Context* parameter is used for user context encoding in the form comma-separated context values. Symbology of the adaptive (contextual) maps is an integral part of Sissi and is defined using SLD specification.

However, Sissi context types are not developed according to Web Map Context Documents specification. Since it extends WMS specification, Sissi is capable of performing rendering functions in terms of merging images from different WMS services. This can multiply request towards existing WMS services. Further, Sissi environment does not involve the usage of WFS services. If clients are capable of adapting geospatial data presentation according to style provided on the bases of the context, than the usage of WFS services is more than legitimate. Also, it is our opinion that the symbology should not be restricted to SLD and that it should be provided by independent services, e.g. style repositories (Bogdanović et al., 2010).

According to previous discussion, our approach, e.g. WMCS, provides the following advantages:

1. Web Map Context Service (WMCS) is a stand-alone Web service, developed according OGC Web Service Common Standard.
2. WMCS relies upon the usage of standard WMS, e.g. it does not demand any extension of existing WMS specification in terms of additional functions or modifications of the existing ones.
3. WMCS relies upon the usage of standard WFS, e.g. it does not demand any extension of existing WFS specification in terms of additional functions or modifications of the existing ones.

4. User context used by WMCS is developed according to Web Map Context Documents implementation specification.
5. WMCS uses geospatial data styling documents from distributed repositories, e.g. symbology used for a particular context is acquired from remote repositories according to context document. At this stage of implementation, WMCS uses styling documents developed using SE or SLD styling language.
6. WMCS does not perform any additional transformation upon images received from WMS. Therefore, it doesn't multiply WMS requests.

The detailed characteristics along with a WMCS specification will be presented in following sections.

ADAPTIVE GEOSPATIAL DATA VISUALIZATION ENVIRONMENT

The main objective of presented research was to design a service that will perform all the tasks needed to help users to get appropriately visualized geospatial data depending on the user context. The system that this service will operate in should be highly modular and mainly built-up of services developed according to existing OGC specifications. The modularity of the system should be observed through its capability to adapt to different users' needs without changing system's architecture. It is our opinion that one of the main advantages introduced by any implementation based on our specification is reflected by the fact that implemented service will not require any extension or modification of services developed according to existing OGC specifications.

According to a name of the specification used for the development of context documents (Web Map Context Documents Implementation Specification), our proposal is named Web Map Context Service (WMCS). Our proposal of WMCS environment, e.g. the architecture of the system that WMCS should operate in, is shown in Figure 1.This system consists of several components that together enable adaptive geospatial data visualization:

- **OGC WMS/WFS Services** – Services that provide geospatial data which can be used in different contexts. In order to be available to system users, these services have to be registered within Web Map Context Service.
- **Symbology Encoding Repository Services (SER Services)** – Services that provide Styled Layer Descriptor or Symbology Encoding styling documents. Styling documents contain information used for appropriate geospatial data visualization. Combined with geospatial data, these documents are used in order to create and register contexts within Web Map Context Service.
- **Clients (desktop, mobile, Web GIS)** – Clients are responsible for displaying geospatial data in the form of maps and should be platform independent. In order to be able to visualize geospatial data appropriately, the client must be able to understand context documents received from WMCS, create requests to services that provide geospatial data, and properly display received data.
- **Web Map Context Service** – Major component of the whole system which is responsible for maintaining information of all registered services and repositories in the system. Further, this service stores information considering registered contexts and provides them to the users.
- **Context Proposal Service** – Customizable service that users can implement according to their needs. The purpose of this service is to enable users to obtain specific context that describes the situation that is of users' interest. Context Proposal Service uses all of the available WMCS operations to define the criteria necessary to use context. The specification and implementation of this service is out of the scope of this paper.

The client may obtain the context document directly from the Web Map Context Service or from one of the existing Context Proposal Service. When the context document is received, client extracts the necessary context information considering layers and styles. Based on extracted information, client forms appropriate WMS/WFS requests and/or Symbology Encoding Repository Service requests. SER Service requests are used in order to obtain context-relevant symbology.

If the context consist layers from the WMS services, the client creates an appropriate GetMap request with information from context document, sends request to the WMS and displays the resulting image. Our system enables the usage of WMS services which support SLD styling as well as WMS services which do not support SLD styling. If WMS services which do not support SLD styling are used, users will not be able to choose styles for layers that these services provide. In this case, they will receive image with default styles applied. On the other hand, if WMS services that support SLD styling are used, clients will embed obtained symbology in the form of SLD document into WMS GetMap request and receive an image with appropriate symbology applied.

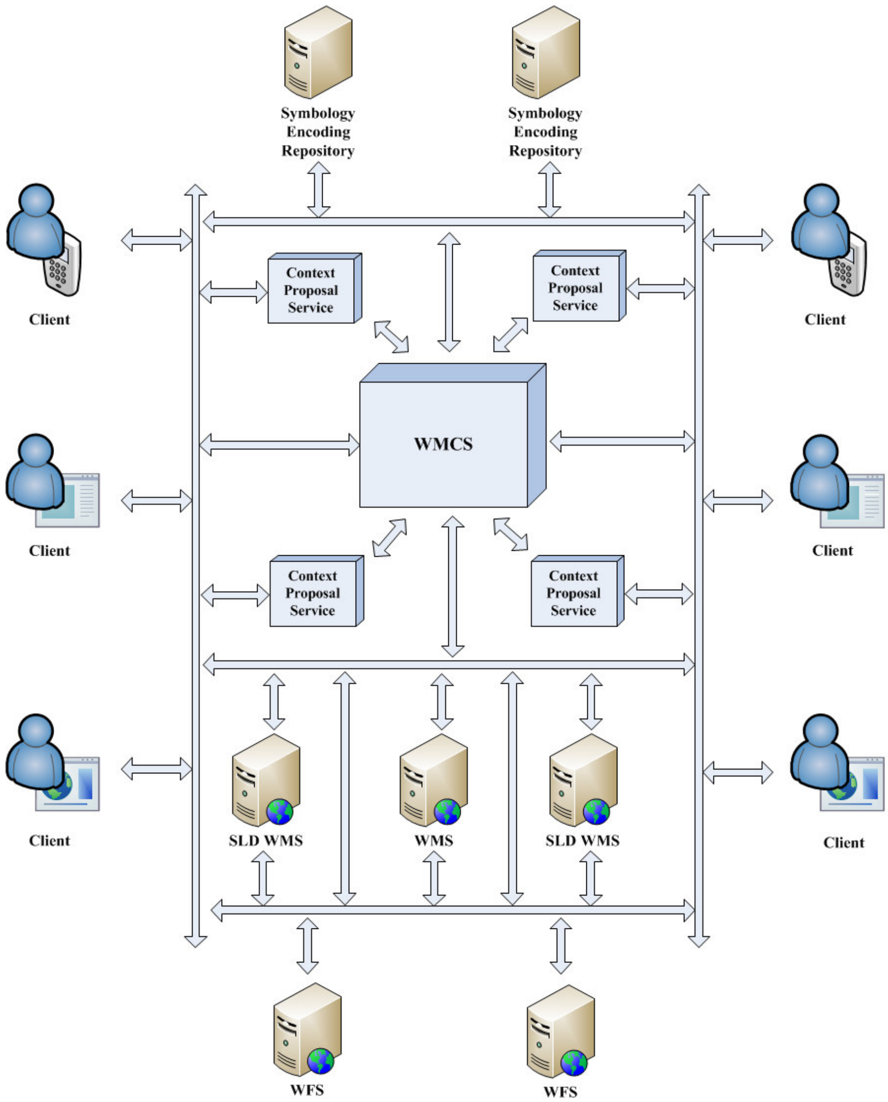

Figure 1: WMCS environment - Architecture of system that allows context-dependent stylized maps

In order to visualize geospatial data acquired from the WFS service, clients must have a mechanism which enables drawing of data acquired from WFS according to styles obtained from one of the Symbology Encoding Repository Services, as shown in Figure 2. First, a client needs to send GetContext request to WMCS. After receiving context document, according to 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.

WEB MAP CONTEXT SERVICE SPECIFICATION

Web Map Context Service (WMCS) stores information considering registered contexts and provides them to the clients. WMCS stores basic data for all contexts in a database while created context documents are being stored on the file system. Each context document used by WMCS is created according to OGC Web Map Context Documents implementation specification (Open Geospatial Consortium, 2005). An example of context document is shown in Figure 3.

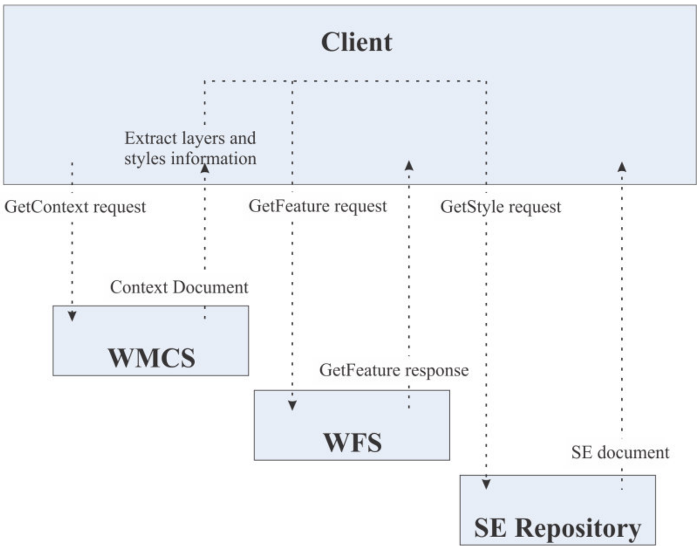

Figure 2: Communication between client and the other components of the system when used WFS service

```xml
<?xml version="1.0" encoding="utf-8" ?>
<ViewContext
  version="1.1.0"
  id="wms_1"
  xmlns="http://www.opengeospatial.net/context"
  xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.opengeospatial.net/context context.xsd">
  <General>
    <BoundingBox SRS="EPSG:31277" minx="7489724" miny="4651755" maxx="7663644" maxy="4859275"/>
    <Title>OGC:WMS</Title>
    <Abstract>Ginis Web Map Server</Abstract>
    <KeywordList>
      <Keyword>WFS</Keyword>
      <Keyword>WMS</Keyword>
      <Keyword>GINIS</Keyword>
    </KeywordList>
  </General>
  <LayerList>
    <Layer queryable="1" hidden="0">
      <Server service="OGC:WMS" version="1.1.0">
        <OnlineResource xlink:type="simple" xlink:href="http://160.99.9.131:8080/ed/wms"/>
      </Server>
      <Name>Transformatorske_stanice</Name>
      <Title>Transformatorske Stanice</Title>
      <Abstract/>
      <SRS>EPSG:31277</SRS>
      <FormatList>
        <Format current="1">image/png</Format>
        <Format>image/bmp</Format>
        <Format>image/gif</Format>
        <Format>image/jpeg</Format>
      </FormatList>
      <StyleList>
        <Style current="1">
          <Name>ts</Name>
          <Title/>
          <Abstract>Style for Transformatorske_stanice layer</Abstract>
          <SLD>
            <Name>ts</Name>
            <OnlineResource xlink:type="simple" xlink:href="http://160.99.9.131/ser"/>
          </SLD>
        </Style>
      </StyleList>
    </Layer>
  </LayerList>
</ViewContext>
```

Figure 3: Example of context document stored by WMCS

A starting point for the development of WMCS specification was OGC Web Service Common Standard (Open Geospatial Consortium, 2010). According to this specification, following operations have been specified:

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

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).
- operation used for registering user contexts.

These operations represent the minimal WMCS operation set. All WMCS operations have the following parameters inherited from Web Service Common Standard (Open Geospatial Consortium, 2010):

- SERVICE – Service type identifier.
- REQUEST – Operation name.
- VERSION – Specification version for operation.

All WMCS operations will be discussed in detail in the following subsections. 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 (Open Geospatial Consortium, 2010).

RegisterService operation

The purpose of the RegisterService operation is to allow the WMS/WFS services and Symbology Encoding Repository Services to be registered within WMCS. Only registered services are available to WMCS users. RegisterService operation requires following mandatory parameters:

- SERVICETYPE –indicates a type of the registered service. Possible values of this parameter are: WMS, WFS or SER.
- URL – The URL of the service that require registration. The URL must be encoded prior to inclusion as a parameter value.

After receiving the RegisterService request, WMCS creates GetCapabilities request on the basis of forwarded parameters and sendsit to WMS/WFS. When a GetCapabilities responseis received, WMCS performs response validation according to OGC WMS/WFS schemas. If the response is valid, basic informationregarding registered service is stored in database. Afterwards, WMCS sends a response stating that a registration process was successful. This response includes ID of context which describes registered service.

The current implementation of the Symbology Encoding Repository Service does not support GetCapabilities operation, so it is not possible to perform validation when registering SER Service. This operation will be implemented in the next SER Service revision.

GetCapabilities operation

The GetCapabilities operation provides client with metadata regarding the capabilities provided by WMCS service. GetCapabilities operation requires following mandatory parameter:

- FORMAT – Output format of service metadata.

A WMCS metadata document contains a set of document sections that are listed in OGC Web Services Common Standard and two additional sections specific to WMCS:

- ServiceIdentification, ServiceProvider and OperationMetadata (inherited from OGC specification).
- ServiceList – Document section that contains list of registered WMS/WFS services with basic information regarding each of the registered services.
- RepositoryList –Document section that contains list of registered Symbology Encoding Repository Services with basic information regarding each of the registered services.

RegisterContext operation

RegisterContext operation provides users with ability to register their context within WMCS. RegisterContext operation requires following mandatory parameters:

- ID – Desired ID for a context that needs to be registered. If a context with specified ID already exists, WMCS returns an exception.
- LAYERS – List of pairs SERVICENAME/LAYERNAME containing the ID of context that describes service and layer name separated by slash.
- STYLES – List of encoded URLs for SLD/SE documents which define layer styles.

WMCS must confirm the existence of each layer and style specified within RegisterContext parameters. If context registration succeeds, WMCS sends a response stating that the registration was successful. This response includes ID of registered context.

GetContext operation

The GetContext operation allows a retrieval of a single or all context documents from WMCS. The GetContext operation can be called with one optional parameter:

- ID – specifies the ID of registered context that will be retrieved. When omitted, WMCS returns ViewContextCollection document that contains documents regarding all registered context.

If the client requests context document representing registered service, WMCS sends GetCapabilities request to WMS/WFS. On the basis of received response, WMCS creates context document and sends it to the client. In case of context describing Symbology Encoding Repository Service, WMCS sends GetLayers operation to SER Service.On the bases of list of layers and styles received within response, a context document is created and sent to the client.

CONCLUSION AND FUTURE WORK

The environment and the specification of Web Map Context Service (WMCS) presented in this paper represent a starting point for the development of GIS environment capable of supporting adaptive cartographic visualization. WMCS specification, as well as context documents that WMCS stores and uses, were developed according to OGC specification. According to presented environment, WMCS does not require any further modifications of the existing services developed in accordance with OGC specification which makes this service easily incorporable into existing interoperable GIS environments. Presented service takes advantage of contemporary GIS clients in terms of their capability of performing geospatial data visualization based on provided styles. Further, symbology used for adaptation of geospatial data visualization is not an integral part of WMCS. Rather, symbology is delegated to styling documents repository services used by WMCS in combination with appropriate contexts. In this development stage, WMCS is capable of obtaining symbology from previously developed Symbology Encoding Repository Services, e.g. WMCS uses styles developed using SLD or SE styling languages.

Future development of WMCS and its environment will give WMCS the ability to use Context Proposal Services (CPS). Thus, WMCS will be able to introduce users with already-existing similar contexts which will lead to faster adaptation of geospatial data visualization and improve reusability of existing symbology. Further, WMCS should 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 should be able to register a XSLT or procedural transformation of its styling language into SLD or SE. It is our opinion that these improvements would lead to WMCS becoming a solution highly applicable within any adaptive geospatial data visualization environment.

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