Architecture of Adaptive Geospatial Data Visualization

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Abstract – **This paper presents our research in the area of Geographic Information Systems (GIS) and adaptive geospatial data visualization. As a result of this research, we have developed architecture of the system that enables adaptive geospatial data visualization according to context-relevant information. This architecture is provisioned as open, scalable and interoperable environment. It is based on SOA and follows the architectural principles of the most prominent SOA examples. Also, our proposal was designed to be highly modular and mainly built-up of service instances developed according to Open Geospatial Consortium (OGC) specifications.**

Keywords – **context, adaptive visualization, GIS, Web.**

I. Introduction

The increasing presence of Internet in all fields of life and business led to mass usage of GIS tools. Nowadays, contemporary GIS tools are used by average users via their computers, smart phones or tablets. A majority of spatial data transfer is accomplished through the Internet via standardized Web Services which sometimes offer large quantities of spatial data. In order to solve the problem of large quantities of spatial data, services need to efficiently and appropriately filter provided data for a single user or a particular situation according to user-defined and/or situation-driven visualization preferences.

In addition to the ability of geospatial data filtering, contemporary GIS tools need to enable control of graphical representation of geographic objects by 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. Different styles used for geospatial data representation are created according to user needs and demands.

Nowadays, GIS tools are able to perform adaptive geospatial data visualization on the basis of the description of the situation and preferred user style. This type of a description usually consists of information that should affect application running and appearance and is referred to as context [3].

Contextual information enables users to indirectly affect geospatial data appearance. Contemporary GIS should be able to receive contextual information and perform the adoption of geospatial data representation according to contextual information. 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 [12]. This service is used as a proxy between users and geospatial data visualization services and is responsible for selecting an appropriate symbology. In order to enable systems for adaptive geospatial data visualization, during design process of system architecture, it is necessary to enable the usage of such service.

The rest of this paper will propose architecture of adaptive geospatial data visualization using Service Oriented Architecture paradigm. This architecture introduce services that are able to perform adoption of geospatial data using existing services designed according to Open Geospatial Consortium (OGC) standards and specifications. These services are specified in accordance with OGC Web Service Common Standard [10]. The proposed architecture enables the usage of distributed geospatial data style repositories [2] and their integration with user contexts. OGC Web Map Context Documents implementation specification [6] has been used for the development of context documents. After presenting adaptive geospatial data environment, these services will prove to be capable of supporting the adaptation of geospatial data representation on both server (such as Web Map Service) and client (desktop, Web, mobile GIS) side.

II. Related Work

In the process of Geo-Information System (GIS) development the importance of visual identification of geospatial data cannot be ignored [7][8]. 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) [9] which was combined with Scalable Vector Graphics (SVG) [16] and XSL Transformation [15] for the purpose of geospatial data visualization, mostly within Web GIS clients [5, 14]. Styled Layer Descriptor (SLD) [8] and Symbology Encoding (SE) [7] styling language specifications have also been proposed by OGC. Aside from languages coupled with specific systems, such as Cartographic Markup Language (CartoML) [1] and Diagram Markup Language (DiaML) [13], 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 [4, 11, 12]. This is one of the reasons

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why an effort has been made in order to make GIS able to adapt geospatial data visualization according to user needs, e.g. towards performing adaptive (contextual) cartographic visualization [4, 11, 12].

A majority of solutions that support adaptive (contextual) cartographic visualization is based on client–server architecture. [11] 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 [12], 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 [4]. 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 [2].

The purpose of the previous discussion is to indicate the advantages that our proposed architecture introduces. The architecture of adaptive geospatial data visualization introduces new stand-alone services (Web Map Context Service and Context Proposal Service) which are able to a perform adoption of geospatial data according to user requirements. These services perform adaptation in combination with existing services which provide geospatial data and styles and do not require any extension of these services in terms of additional functions or modification of the existing one. The basis for development of introduced services is OGC Web Service Common Standard (Open Geospatial Consortium). Styles that are used for adaptation of geospatial data are acquired from previously developed remote repositories [2]. Styling document is created according to Symbology Encoding [7] or Styled Layer Descriptor [8] specifications. User context used by services within proposed architecture is developed according to Web Map Context Documents [6] implementation specification.

III. Architecture

The main objective of the proposed architecture and its components is to provide GIS users with appropriately visualized geospatial data according to user-relevant information, e.g. user context. The system is built on the basis of Service Oriented Architecture (SOA) principles and contains services which provide geospatial data, perform visualization and maintain user contexts.

The architecture of adaptive geospatial data visualization uses existing services that provide geospatial data and style documents. These services are developed according to available OGC standards and specifications. Furthermore, proposed architecture introduces new services which are responsible for maintaining context documents and the adaptation of requested geospatial data according to user-defined visualization preferences.

The architecture consists of several layers that include components responsible for adaptive geospatial data visualization, as shown in Fig. 1:

- **Geospatial Data Repositories** – This layer consists of any available data repository which provides geospatial data: legacy RDBMS, DBMS with spatial extension or file system.
- **Data Access Services** – Services that provide geospatial data (WFS) and perform their visualization (WMS) are the components of data access layer. The proposed architecture enables the usage of WMS services which support SLD styling as well as WMS services which do not support SLD styling. Data access services 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. Users use layer information from any of the registered services to create context documents according to their needs.

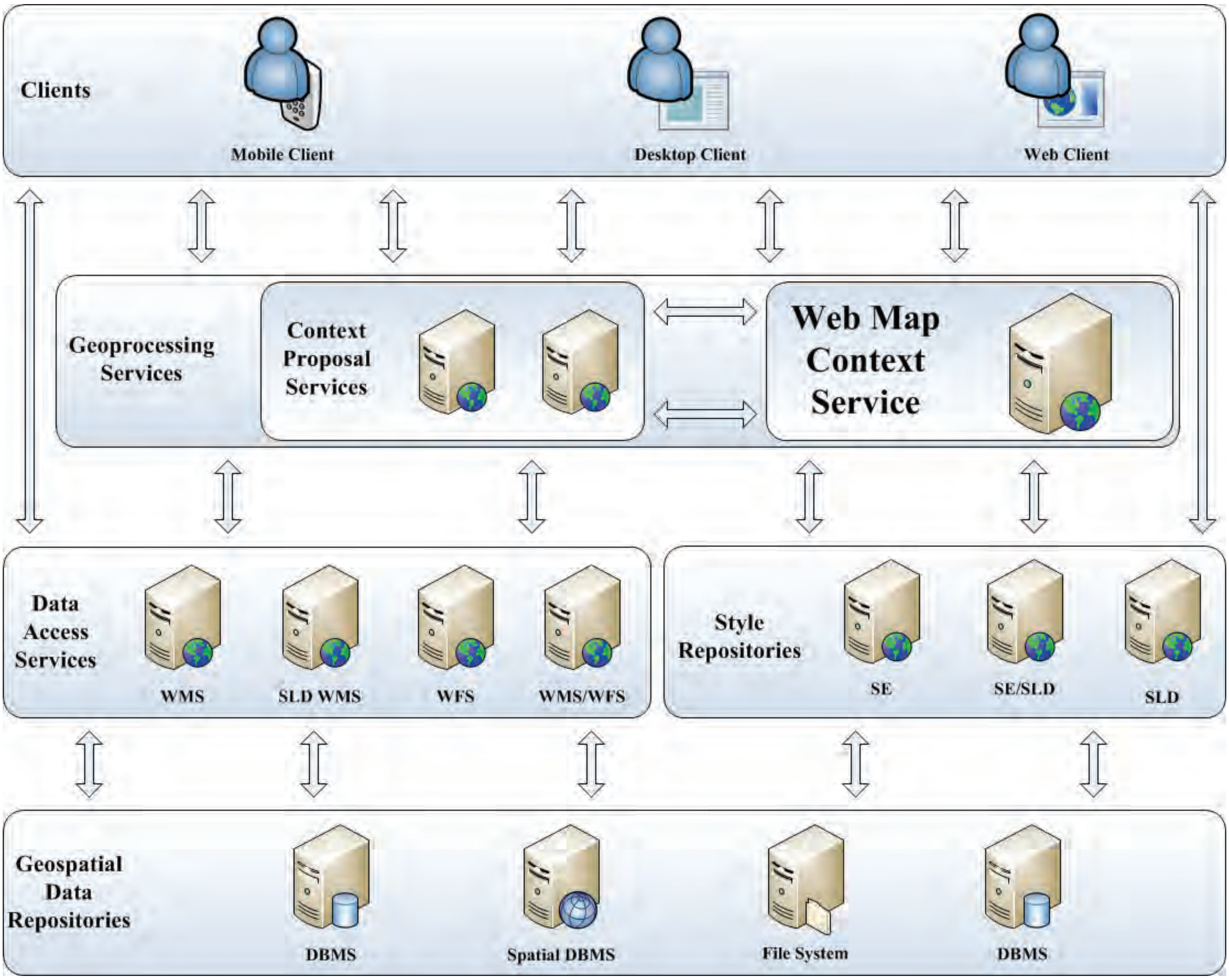

Figure 1. Layered architecture capable to perform adaptation of geospatial data

- **Style Repositories** – Services that provide styling document developed using Styled Layer Descriptor or Symbology Encoding styling language. Styling documents contain information used for appropriate geospatial data visualization. These documents are used in order to create and register contexts within Web Map Context Services. These services also have to be registered within Web Map Context Service.
- **Geoprocessing Services** – The geoprocessing services layer is responsible for the maintenance of the user context and represents the foundation for the adaptive visualization processes. This layer uses user context information stored in context document created according to OGC Web Map Context Documents implementation specification. Furthermore, this layer consists of two main services: Web Map Context Service (WMCS) and Context Proposal Service (CPS). WMCS maintains information considering all registered services and style repositories in the system, maintains information considering registered user contexts and provides them to the clients. CPS is an open, customizable service that can be implemented by a third-party 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, e.g. probably similar to the situation the user is currently in.
- **Clients** – Platform independent GIS applications capable of displaying geospatial data according to user's context. These applications have to be able to understand context documents received from one of the geoprocessing components. Also, these applications have to be able to create requests to data access components or style repositories and properly display received data. 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. Client is responsible for embedding SLD document into WMS request if the SLD styling is supported by the WMS service. 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 Style Repository Services.

Architecture of adaptive geospatial data visualization was designed to be highly modular and mainly built-up of service instances developed according to Open Geospatial

Consortium (OGC) specifications. The system developed according to the presented architecture is capable of adapting large quantities of geospatial data based on different users' needs without changing its internal structure. This ability illustrates the level of system's modularity. Another advantage of our proposal is introduced through the usage of WMCS instances and reflected by the fact that WMCS instances do not require any extension or modification of the existing service instances developed according to OGC specifications. Therefore, any existing service oriented GIS architecture can easily adopt WMCS instances and become capable of performing adaptive geospatial visualization.

IV. Conclusion

In this paper we have presented architecture which is starting point for the development of GIS environment capable of supporting adaptive geospatial data visualization. Through the presented architecture we introduce new services developed according to OGC Web Service Common Standard. These services are responsible for efficient and appropriate geospatial data filtering. Presented environment does not require any further modifications of the existing services developed in accordance with OGC specification which means that this architecture design can be used for the extension of an existing interoperable GIS environment. Furthermore, symbology used for adaptation of geospatial data visualization is delegated to styling documents repository services used by WMCS in combination with appropriate contexts.

Future research and development of the presented architecture should cover development and extension of Web Map Context Service in term of new operations. 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 should be able to register a XSLT or procedural transformation of its styling language into SLD or SE.

Since the Context Proposal Service allows obtaining of already-existing similar contexts, future research should cover development of different methods for context similarity according to situation the user is currently in.

It is our opinion that these improvements would lead WMCS and the proposed system towards becoming a solution highly applicable within any adaptive geospatial data visualization environment.

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