An Architecture for Geographic Information Systems on the Web - webGIS

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***Abstract*— Geographic Information Systems for the web (webGIS) are being implemented for different purposes. In this context, one of the greatest challenges is to integrate different sources of geographic data, as well as the visualization of this information using maps in an interactive environment. This paper presents a proposal for architecture for the webGIS with interoperability between different sources of heterogeneous data, as well as the visualization of maps in different formats with components implemented with Web 2.0 technology. The architecture was validated through a case study that implemented a webGIS to academic research at the Geosciences Institute of the University of Brasilia.**

Keywords-Geographical Information System; webGIS; Geographical database; Map Visualization.

I. INTRODUCTION

Geographic data, having been collected, is now available in a wide variety of formats. Geographic data is available in files, databases or Geographic Information Systems (GIS) [1]. A GIS is frequently defined as the combination of a database management system, a set of operations for exploring data, and a graphic display system that is used for geospatial analysis. These GIS analyses have the main purpose of supporting decision making and modeling some of the possible consequences of those decisions [2][8][16][20]. GIS environments are also cartographic tools that facilitate building maps and examining the impacts of changes to the maps interactively [1][3][5][9][11][12].

Currently, GIS on the web (webGIS) is being developed, and one challenge in that environment is interoperability among heterogeneous databases. For interoperability of the data, the web services technology is being used [15]. The standard set by the OGC (OpenGIS Consrtium) proposes the open service architecture of web GIS to support data-interoperability. And, it suggests the GML (Geographic Markup Language) based on XML to exchange the data between the web client and the web GIS [6][7]. REST [22] technology is also used to support interoperability with geographical databases.

For the visualization of maps in an interactive way, Web 2.0 technology is being applied through different components of RIA (Rich Internet Application). As is observed in [10], this technology is being applied for the development of web-GIS. Web mapping applications such as Google Maps, Google Earth, Microsoft Bing Maps and Yahoo Maps are usually considered good examples of Web 2.0 [15].

This paper presents an architecture for webGIS based on Web 2.0 and interoperability among different geographical data. The architecture is based on web services and can be used with open or owner map and database servers.

The content of this paper is divided into the following sections: 2 – basic concepts about webGIS are presented; 3 – the proposed architecture is defined; 4 – related works, which are analyses; 5 – Case Study, where the architecture was used to develop the GIS for the Geosciences Institute of the University of Brasilia; and finally, 6 – the conclusions.

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II. WEBGIS

Web GIS is any GIS that uses Web technologies. The simplest form of webGIS should have at least a server and a client, where the server is a Web application server, and the client is a Web browser, a desktop application, or a mobile application [15][4].

With regard to the architecture of a webGIS, the architecture based on three layers is most commonly used: User Interface Layer, Application Server Layer and Database Layer [17][19][21]. Some authors considered four layers, where the integration layer is added on the architecture webGIS, which is based on web services [14].

The User Interface layer serves as a graphic user interface (GUI) to present the result of spatial data, allowing the end users to interact with the backend services

The Application Server layer communicates with multiple data sources via the data integration layer, and interacts with end users to analyze and manipulate data coming from data provider services

The Database layer of data provider services, is a set of remote data provider services for data sharing. Each data provider service offers a set of interfaces through which client applications can pull remote data in and manipulate the data.

III. PROPOSED ARCHITECTURE

The model proposed (Figure 1) presents an abstract architecture for a webGIS. In this model we observe a set of classes developed that integrate with one another and servers of interoperability, and web services in the treatment and insertion of information, as well as in the availability of data for the final user.

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The use of web services and the development of classes that read and organize the overlay of data provided with servers of owner interactive map or of open software, provide a hybrid tool that can use WMS, WCS or REST for the presentation of layers on the web in a single RIA application utilizing web services.

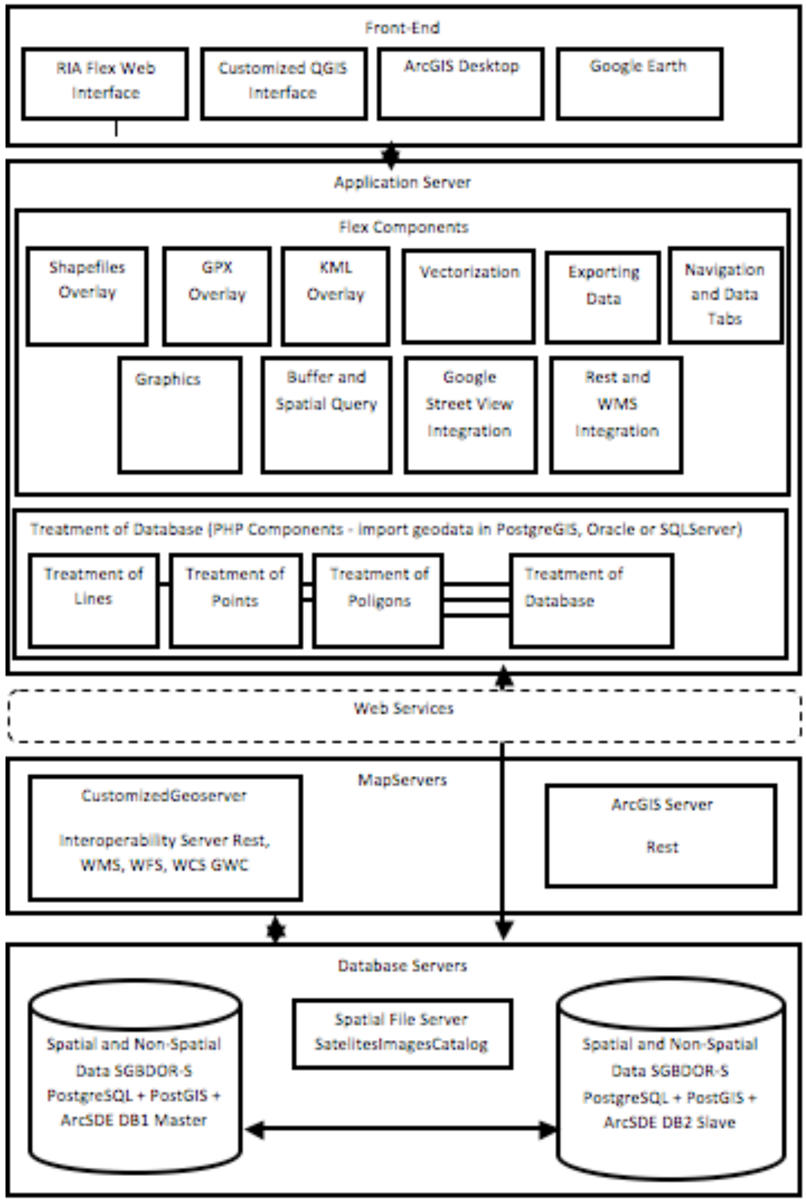

Figure 1. Abstract Model of the proposed architecture

Each component of the abstract architecture is described as follow.

- Shapefile Overlay

Component that enables the opening of shapefile files and their attributes, providing the overlay of geometries available in .shp files in the web Flex environment, the constant attributes in .dbf files are presented in a tabular format and related to the correspondent geometry. The features that can be viewed are: line, point, or polygon. In order to do this simply click on the tool of the folder with the zipped file containing minimally formatted .shp, .shx and dbf. Files. In case the set of files is projected in a system distinct to the map base, the inclusion of the compacted file .prj is necessary for the system to complete re-projection. In the construction of this component were used methods for the reading of attributes of the DBF written in ActionScript and also for reading the files in .shp format about the same language.

As it is necessary to open the files in a zipped format a unzipping package was used on files also written in ActionScript.

- GPX Overlay

The great quantity of Garmim brand GPS field equipment users was an enormous motivator in the development of this component, which makes the overlay of files downloaded directly from equipment of this type possible. All of the waypoints available to track overlays of a line where the initial point is presented in green, the path in yellow and the end in red are presented. The attributes given to the paths are shown in a floating table. The standard open GPX format was considered in the construction of the component.

- KML Overlay

This class provides the opening and comparison of the routes generated in Google Map platforms, and also in simple files in KML format, the available attributes in the referred to file are also presented in splints through floating panels.

- Vectorization

The class that serves vectorization and release in distinct database formats such as lines, points and polygons. Algorithms for the calculation of the area and perimeter are also in this class, if sending to the database is not necessary, the user can opt to save the designed features on a local disc. This component acts directly linked to the components in PHP for recording in database, the Flex interface, responsible for the instruments of vectorization accessing through web-services, routines that insert data in a determined data base already established. After the insertion one can, on moving or updating the map, visualize the geometry already inserted. This is possible because the feature is available as a service on the map base, facilitating the availability through ArcGIS Server as well as the Geoserver Java. For the case of use presented here the Post GIS type data was used directly.

- Graphics

Tools for which geographic database tables, or simply web services about them, can be chosen by way of selection boxes, from which one can select numerical attributes and vectorize an area on the screen resulting in pizza or bar form graphics. These are interesting analytical tools for statistical census data, however, with geographic presentation and selection.

- Exporting Data

Totally integrated components or Geoserver Java interactive server maps, can be made through this class, with the selection and later exportation and download of layers or a part of them in diverse formats such as shapefile, csv, pdf, XLS, KML, KMZ, JPG, PNG and others. Through this component, whatever is selected by the user on the screen, with the exception of the shapefile and Google formats, will be presented for download with a quadrant. Thinking a step ahead, as of yet developed, will be the component that can make the clip using the Geoserver server.

- Buffer with Spatial Query

Tools of bufferization through which complete features or a part of their registers can be used to create buffers. After the conclusion of this step the user of the class can once again select features, however, now to execute special queries about the buffer presented on screen. The result presented can be saved so that it is not necessary to complete the whole process again. Methods for selection of registers and services for generating the buffer were used, soon after the execution of the consultation and selection of attributes of geographic features about which one need obtain information, a spatial consultation is done, which outlines the occurrences of information inside the areas of buffers intersected.

- Google Street View Integration

A developed component that integrates with the Google Street View Platform, so that the information can be visualized in two dimensions, and through which one can navigate on maps, in addition to visualizing, in a part of the frame, the entire Google Street platform base, which always synchronizes the observation points with the street navigation.

- Integrated Overlay REST and WMS

This is the most important component developed, since it makes possible the integration of different formats of interactive maps hybridizing the framework, through which one can make use of standard REST web services available through the software ArcGIS Server as well as the Geoserver and makes the overlay transparent to the user of standard WMS and WFS web services. Actually tasks such as this are already available in API 2.x of the ESRI.

- Navigation and Data Tabs

A component of presentation and formatting grids was built aimed at improving the visual aspect of register lists extracted from the database. There is a great interaction between the navigation and consultation of attributes related to the geometry visualized.

- Treatment of Geographic Database

This component aims at adopting the tool of a set of classes capable of treating incoming information from the interface that will be sent to the database, and through this one can select which type of database will be used and the classes will be the interactions necessary for a correct treatment of distinct types between the manufacturers of SGBDs. Treatment of Geographic Features: set with the minimum rules necessary to avoid classical errors at the moment of vectorization, such as the creation of polygonal ties. Through this, perimeter and area are also calculated and different symbologies can be attributed to the design features, such as, completing the recording in databases or in the text format to be saved in a locale and overlay. These classes were developed using PHP language in standard MVC and object orientated, and web-services were made available, which it was necessary to send the textual and geographic information, vectorized on screen by way of the Flex interface, and the information of authentication aiming at increasing the degree of security of the tool since, these components interact directly with the database chosen.

A. *Development of the Architrcture*

For the development of the SIG, various program languages were chosen, including: Flex, Action Script, PHP ,

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Java Script and Ajax. Java programming language was used in the customizations done for the Geoserver software, and was the same language in which the software was written.

In the development of the SIG web interface, the standard RIA, the Flex and Action Script was used. The API for Flex of ESRI was used as the core of the application. Beginning with the basic navigator, diverse components were used in the solution. Among them components capable of doing the overlay of layers in WMA and WCS format provided by software such as Geoserver, turning the navigator maps in SIG hybrid, capable of consuming data originating in the ArcGIS Server and/or the Geoserver. Another point to be considered is the framework developed in PHP language, oriented to objects and in standard MVC—Model View Controller. This server not only does dynamic construction of the electronic forms, but also treats data stemming from vectorization and, afterward, stores them in special extensions available in databases such as PostGIS of the PosgreSQL and Spatial of the Oracle.

Other components, such as the integration of the Google platform, with overlay for shapefile, KML and GPX bufferizaiton, spatial and graphic queries were developed and incorporated in the application.

One of the advantages presented by the set of components developed is not only the creation of the components that approximate the web platform of a GIS client/server environment, but the concept of classes makes the use of technologies with platforms based on free software viable, such as, Geoserver or others that generate web services in standard OGC, including WMS and WCS through the overlay of layers. Other advantages visualized were the speed with which the applications were created based on the set of codes developed.

The customization completed in the software Geoserver, together with the system customization done on the Geoserver software, aims at accelerating the process of making web services for maps available so that they can be incorporated quicker in the context of the application, although it is not necessary to have such a module to make use of the Geoserver software together with the system.

IV. Related Work

The proposal presented in this paper is the architecture of webGIS, which has the characteristic of components based on web 2.0 for visualization of spatial data. Our proposal has a layer of interoperability with free and own mapping server and different Geo-DBMS.

Shunfu Hu [19] presented an architecture for development web-based GIS applications. The webGIS was based on Microsoft Visual Basic. Microsoft Internet Information Server (MIIS) was employed as web Server and ESRI MapObjects Internet map Server as map Server. Unlike our proposal, the architecture present in [19] is not interoperable.

Boucelma et al. presented [1] a WFS-based mediation system for GIS interoperability. The functional architecture of the geo- graphic mediation system is mainly composed of three layers: a GIS mediator, Web Feature Servers (WFS) and data sources. In [1], the integration of query capabilities available at the sources and a geographical query language to access and manipulate integrated data is addressed. Differently, our architecture integrates the data source and the components Treatment of Database and Buffer and spatial query.

Majchrzak and More, in [10], cover how Web 2.0 technologies can be used to develop GIS through interaction with users. In [10], the aide volunteers in disaster situations is presented, using Google technologies. Our proposal is an abstract with different front-end, map server and Geo-DBMS, which can be used with Google technologies or others.

Zongyao and Yichun proposed, in [14], a service-oriented architecture for spatial data integration (SOA-SDI) of a large number of available spatial data sources that are physically sitting at different places, of which the development web-based GIS systems were based on SOA-SDI, allowing client applications to pull in, analyze and present spatial data from those available spatial data sources. Lu, in [18], defined a GIS platform architecture as a multi-layer architecture that integrated the web service, Servlet/JSP functions and GIS APIs based on the framework of J2EE infrastructure. The GIS system can be accessed by many different computers in networks with different kinds of operating systems. It is a distributed, platform independent system architecture. The data are stored and managed with EJB. Frehner and Brandli [20] presented the Virtual Database that consists of a framework for web-based retrieval, analysis, and visualization of spatially related environmental data based on the integration of distributed data. This architecture is based on web services. The proposal presented in [14][18][20] has the interoperability properties, however, our proposal supports more geographic data formats.

V. Case Study

The development of a public consulting system of academic research built on a GIS (Geographic Information Systems) paradigm, composed of an interface of interactive maps available on the Internet, using geographic databases, servers of interactive maps that generate services on the web and the use of languages and technologies of the latest generation for the layer of presentation and interaction with users. In Figure 2, we present the initial vision of the system.

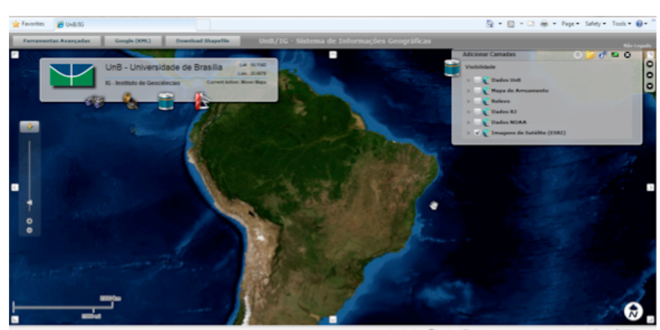

Figure 2. Initial View of the System

Various geographic web services are integrated, such as wind velocity and direction services of the American NOOA, with the rest platform of the ESRI as a mosaic of world images and services of maps from diverse Brazilian institutions. Thus, many services were in standard WMS and WCS, while services in standard REST were integrated guaranteeing then, a good degree of interoperability and sharing.

In Figure 3, we see the geographic features presented with the richest detail when using zoom tools on the map; at this level of zoom, one can see rural properties in salmon tones, as orange highlights the human settlements, and airstrips, train tracks and the main rivers can also be seen at this level. An altimeter base completes the background. The features not used as web services were stored in SGBD PostgreSQL with PostGIS.

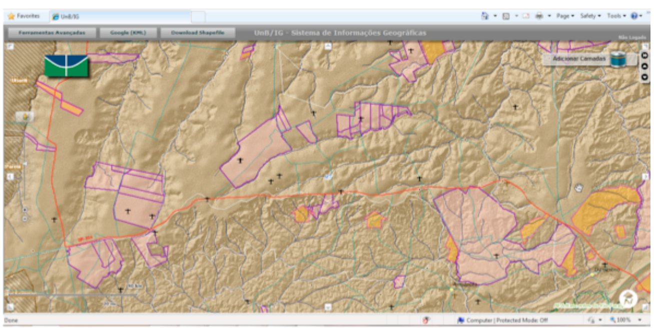

Figure 3. Zoom of detailed information of the geography mounted

The transparency of the maps can be altered and diverse layers of information of the same geographic area can be presented; this is a resource that Flex technology provides, which is useful and has great visual impact. In Figure 4, on selecting the area of the city of Rio de Janeiro we have the system fusing local data with data from web services of other institutions, such as: the Pereira Passos Urban Institute of Rio de Janeiro and the Brazilian Institute of the Environment and Renewable Natural Resources—IBAMA.

In Figure 5, we see the integration with the Google Street View platform. A point of observation was located in front of the Metropolitan Cathedral of the city of Rio de Janeiro; one can see in the upper part of the screen a higher view of the area and in the lower part a 3-D view obtained by the Street View platform of the same region and with the same direction of the arrow pointed.

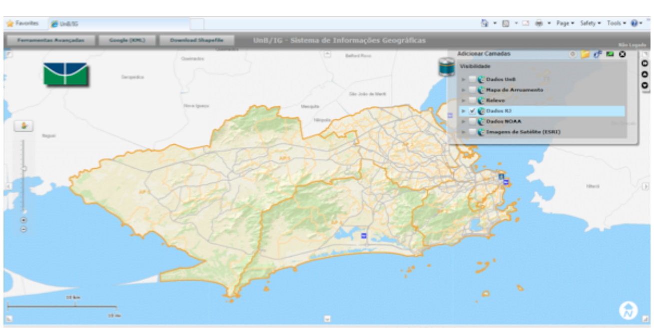

Figure 4. Zoom of the city of Rio de Janeiro

Figure 5. Integration Google Street View

Research tools of academic works were developed, and through these one can find scientific articles or studies completed in the research area.

Tools such as buffer and spatial queries were implemented and integrated; below shows the two operating together, according to data presented in Figure 6.

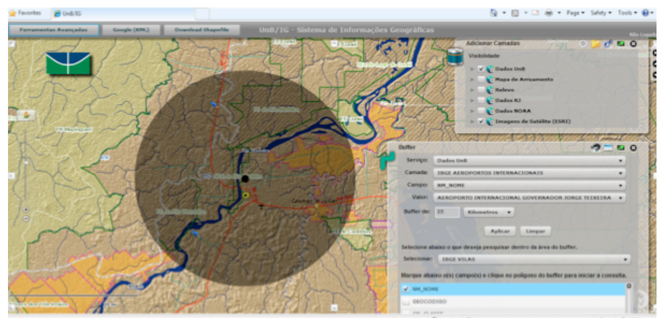

Figure 6. Buffer Tool and Spacial Query

Spatial graphic generating tools permit an evaluation of areas excessively inventoried for a determined resource or the identification of areas in need of particular studies, or identification of the needy areas of the given study, as presented in Figure 7.

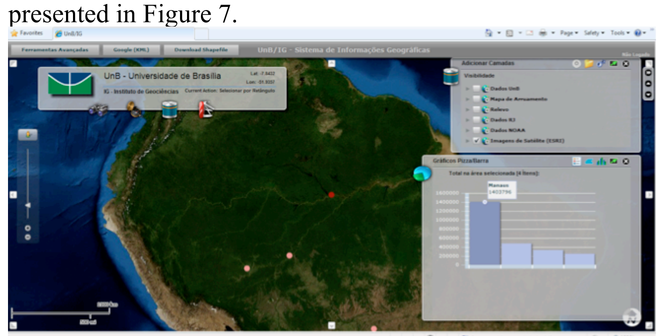

Figure 7: Spatial consultancy tools for generating graphics

VI. CONCLUSION

The architecture presented in this paper proposes a tool of rapid implantation and availability of geographic data through the web, with a set of services made available, which can easily integrate data of structured systems such as,

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consumption of information originating from diverse data sources.

The architecture proposed responded well to the system of application, much as the same being used for the development of other webGIS. Recently IBAMA adopted the architecture proposed in this work in the implementation of webGIS for the monitoring of its field supervision operations; through the set of components available, the information of operations and navigation of airships and roadways, always in a geo-referenced way are presented. Similarly, the effect of agents or the quantity of apprehension and automations are informed through structured systems and presented in a spatial way on the platform.

The next step is to implement the proposal architecture independent of API ESRI.

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