GISEIEL: AN OPEN SOURCE GIS FOR TERRITORIAL MANAGEMENT *

Pedro A. González

Servicio de Asistencia Técnica a Municipios. Diputación Provincial de A Coruña. 15006 A Coruña, Spain
pedro.gonzalez@dicoruna.es

Miguel Lorenzo

Servicio de Organización e Innovación Tecnológica. Diputación Provincial de A Coruña. 15006 A Coruña, Spain
miguel.lorenzo@dicoruna.es

Miguel R. Luaces, David Trillo, José Ignacio Lamas Fonte

Database Laboratory. University of A Coruña. 15071 A Coruña, Spain
luaces@udc.es, dtrillo@udc.es, jilamas@udc.es

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Abstract: The provincial government A Coruña, in Spain, has been working on the last years in the construction of a geographic information system for the management of its territory. The result of this work are three software products: *WebEIEL*, *gisEIEL* and the *ideAC node*. *WebEIEL* is the web application that publishes the information on the Internet. *gisEIEL* is the desktop application that is used by the provincial government and the municipalities to create, query, visualize, analyze and update the information in the system. Finally, the *ideAC node* is a spatial data infrastructure that uses international standards to publish the information as a part of the Spanish spatial data infrastructure. In this paper, we describe the functionality and the architecture of the system and we present the problems that we had to face during the development of the system and the solutions that we applied.

1 INTRODUCTION

The Spanish government requires every provincial government to conduct each year a survey on the situation and condition of the infrastructure and facilities in each municipality (named EIEL from the Spanish *Encuesta sobre Infraestructura y Equipamientos Locales*). This information is used by the Spanish and the provincial governments to discover the funding needs of each municipality and to propose actions to balance the living conditions in the different municipalities

The province of A Coruña is located in northwestern Spain. With more than one million inhabitants and almost eight thousand square kilometers, it is densely populated with more than a hundred and twenty-five inhabitants per square kilometer. In the year 2000, the provincial government of A Coruña decided to broaden the goals of the EIEL with these new tasks: (i) to extend the information to be collected, both in terms of the different kinds of elements to be sur-

veyed, and the amount of information for each particular item, (ii) to reference the items surveyed to its geographical location or extent, and to construct a geographic database and applications for its management, and (iii) to publish the data through a user-friendly GIS web application and through a spatial data infrastructure to make it available to all the citizens of the province.

These goals were achieved through a collaboration with the University of A Coruña. The work was carried out in several phases. In the first phase, from the year to 2000 to the year 2003, the geographic location and/or shape of more than 100 different types of entities were surveyed to construct a database of about seven gigabytes of alphanumeric and geographic information. A large group of students from the Civil Engineering school and the Architecture school (about a hundred people) collected the data by direct observation or interviewing the responsible staff in each municipality. All the software engineering issues in the project were the responsibility of the Database Laboratory of the University of A Coruña. Their task was to develop all the GIS applications required to insert, maintain, manage and publish all the collected data. The problems that

appeared during this task are described in (Brisaboa et al., 2007).

Once the database was created and populated, the second phase was the development of applications to exploit the data. This was done between the years 2004 and 2006. The first application (called *gisEIEL*) was a desktop application deployed at the provincial government and used by its staff to visualize, analyze and keep the alphanumeric and geographic data updated. The second one was a web-based GIS (called *WebEIEL*) that can be accessed over the Internet (Deputación Provincial da Coruña, 2008).

During the third phase, from the year 2006 to the present day, the provincial government decided to migrate the application to open source software and to implement a spatial data infrastructure (named *ideAC node*) that publishes the information using standards as a part of the Spanish spatial data infrastructure. In this paper, we describe this migration process, the functionality and the architecture of these applications and the problems that had to be faced during their development process. The rest of the paper is structured as follows: first, we describe in Section 2 the migration process from the first version of the applications developed using proprietary software to the current version developed using open source software. Then, we describe in Section 3 the functionality and the architecture of *WebEIEL* and the *ideAC node*. After that, Section 4 describes the application *gisEIEL* paying special attention to the functionality and the methodology for the survey. Finally, we end the paper with conclusions and future work in Section 5.

2 MIGRATION TO OPEN SOURCE SOFTWARE

When the project started in the year 2000, all the applications were implemented using the GIS development tools provided by Intergraph, particularly Geomedia Professional and Geomedia Web Map (Intergraph Corporation, 2008). There were two main reasons for this decision. First, time and cost requirements for the project forced us to use existing GIS development tools instead of implementing the applications from scratch using custom-developed modules. And second, when the analysis and design of the system started in the year 2000 the relevant international standards were not mature. The first consequence of this decision was that the applications only worked on a Microsoft operating system. Given that the provincial government uses Linux on their servers, the applications had to run in a virtual machine with the

consequent loss of efficiency. Another consequence was that the web publishing service (Geomedia Web Map) was only compatible with Microsoft Internet Explorer. Therefore, the users were forced to use this web browser. The third consequence was that the data had to be stored using a read-only proprietary format (Geomedia SmartStore) in order to achieve an acceptable efficiency rate in the web publication. This implied that the information was duplicated with all the problems associated to this fact (e.g.: complex publication process and incoherency problems). A final consequence was that Geomedia Web Map did not conform to the Open Geospatial Consortium (OGC) standards when the applications were developed, therefore, the applications could not be used as a spatial data infrastructure.

These problems, along with the publication of the INSPIRE directive (INfrastructure for Spatial InfoRmation in Europe (European Commission, 2008)), determined a deep change in the philosophy of the project and in the selection of technologies that are the foundation of the system. In the year 2006, the provincial government and the Database Laboratory started a new project to migrate all the system to open source software and to create a node of the Spanish spatial data infrastructure for the province of A Coruña (Pedro A. González, 2004). Figure 1 shows the evolution of the system. The architecture of the system using proprietary software is depicted on the left side of the figure. The new architecture using open source software is shown on the right side of the figure. The equivalent components on each architecture are depicted with boxes and arrows joining them.

The first task of the process was the migration from Microsoft SQL Server (Microsoft Corporation, 2008) to PostgreSQL (PostgreSQL Global Development Group, 2008) and PostGIS (Refractions Research, 2008). This implied a migration from a GIS architecture using opaque binary large objects for the representation of geographic features to a GIS architecture using an extensible database system following the Simple Features for SQL standard (OGC, 2006a). The migration of the data was performed by a custom application that used the Geomedia Professional API to read the information from the source database and created the SQL scripts used to restore the database in PostGIS.

The second task of the process was the migration of the web application (*WebEIEL*) and the construction of the *ideAC node*. The *ideAC node* includes a Web Feature Service (OGC, 2005), a Web Map Service (OGC, 2006b), a catalog service (OGC, 2007a) following the ISO19115 standard (ISO/IEC, 2003) and the Spanish metadata profile (Consejo Superior
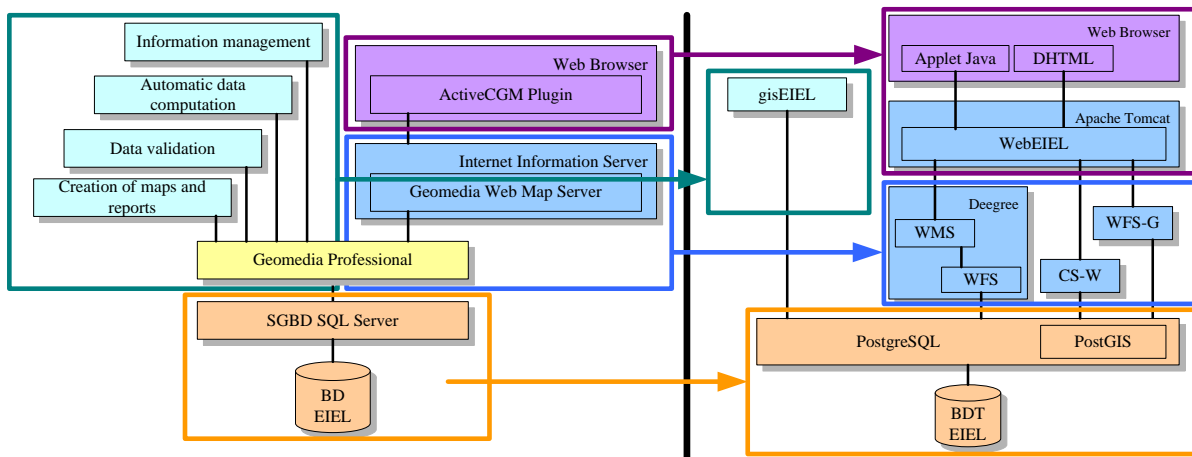
Figure 1: Migration of the architecture from proprietary software to open source software.

Geográfico, 2005b), and a gazetteer service (OGC, 2008; Consejo Superior Geográfico, 2005a). Furthermore, the web application was redesigned to use J2SE technologies in the implementation of the server side. Finally, the client side user interface was also redesigned. Instead of displaying the geographic information using an ActiveX plugin provided by Intergraph (Active CGM Plugin), two different user interfaces were developed using a Java applet and dynamic HTML. This improves the accessibility of the application because it does not require an specific web browser from the user.

The last task of the process was the migration of the desktop applications for the management of the information in the system. We left this task for the end of the process because there was no software component fulfilling our requirements at the beginning of the project. The migration process also allowed us to integrate in a single application several applications that were developed in the first phase of the project, namely: (i) the desktop application for the management of the information, (ii) the applications that computed in an automatic way some information, (iii) the applications for the validation of the information in the database, and (iv) the applications to generate printable maps and reports.

3 *WebEIEL* AND THE *ideAC NODE*

The right side of figure 1 shows the architecture of the *ideAC node* and the *WebEIEL* application. The bottom part of the figure shows the database of the EIEL of A Coruña. The information collected consists only of vector-based geographic features, that is, no coverages are needed for the information in the data model.

Therefore, the only requirement on the database management system (DBMS) is to conform to the Simple Features Specification for SQL standard (OGC, 2006a) proposed by the OGC and ISO. In our case, we have chosen PostgreSQL (PostgreSQL Global Development Group, 2008) with the extension module PostGIS (Refractions Research, 2008) for the representation of the geographic information. The main reason for this decision is that PostGIS is more mature in terms of the implementation of the SFS standard. For instance, all the spatial operators proposed by the standard are completely implemented in PostGIS whereas other database management systems, such as MySQL (MySQL AB, 2008), implement these operations using the bounding box of the geographic features. This functionality was considered more important than the fact that PostGIS is slightly slower than other alternatives.

The following level of the architecture is composed by the services of the *ideAC node*: the Web Feature Service (WFS), the catalog and metadata service (CS-W), the gazetteer service (WFS-G) and the Web Map Service (WMS). The Web Feature Service (OGC, 2005) is in charge of serving the geographic information in the database encoded using GML (OGC, 2007b). This file format is an XML application for the representation of geographic information. By using this service, any client application can retrieve the information in the database in a format that preserves the identity and the alphanumeric information associated to each geographic feature. Deegree (lat/lon GmbH, 2008) was used for the implementation of this service because of its efficiency even though the configuration of Deegree is very complex.

The catalog and metadata service allows the users

to query and discover the information that is available in the node, the way in which the information in the node is related to each other, and all the additional information that can be assigned to each information element following the ISO 19115 standard (ISO/IEC, 2003). We implemented this service from scratch because no existing implementation fulfilled our requirements.

Regarding the gazetteer, we also had to analyze, design and implement a service following the Gazetteer Service for WFS specification (OGC, 2008) defined by the OGC and the definition of the Spanish Gazetteer Model (Consejo Superior Geográfico, 2005a) proposed by the Spanish National Geographic Institute. The service was designed as a set of independent modules that enable reusability.

The last service of the *ideAC node* is a Web Map Service (OGC, 2006b). This service is used to produce cartography from the geographic information stored in the system. In this case, the result of a query is a map with the information requested encoded using an image format using the visualization styles requested. The identity of each individual element and the alphanumeric information is lost in the process. Therefore, the result of this service can only be used to display cartography but not to retrieve the original information. We also used Deegree (lat/lon GmbH, 2008) as a basis for the implementation of this service.

The topmost layer of the architecture is formed by the application *WebEIEL*. This application is in charge of providing a user-friendly interface to query and visualize the geographic information, the metadata catalog, and the gazetteer. We decided to offer two different versions of the user interface targeted at two different user types. The first type of user interface was designed for advanced users. Its main characteristic is that it works in a very similar way to a desktop GIS visualization tool. This user interface uses active vectorial maps encoded using the SVG file format (World Wide Web Consortium (W3C), 2003) and the visualization is performed by a Java applet. The main advantage of this user interface is that it can provide many more functionality than a pure web application. Moreover, the user interaction is bigger and the quality of the maps is higher because they are in a vector-based format. The main drawback is that this user interface requires a higher knowledge level from the user because the Java virtual machine must be installed in the computer and its learning curve is more steep. Furthermore, the application needs more time to start and the information requires a longer time to load.

The second type of user interface was designed for common users whose only interest is visualizing the geographic information. This user interface is more simple because it uses images to display the cartography and it is implemented using only dynamic HTML and JavaScript. Therefore, it can be used in any web browser without having to install any additional software. Hence, it is the most suitable for non-expert users in GIS applications.

We designed and implemented most of *WebEIEL* from scratch. The only third-party component that we used is MapBuilder (Community MapBuilder, 2008) as a basis for the user interface based on dynamic HTML and JavaScript.

4 *gisEIEL*

gisEIEL is the desktop application used by the staff at the provincial government for querying, visualizing and correcting the information in the database. Furthermore, it is also used by the surveying teams to update the information of the survey every year. Therefore, the application is used by around ten people in the provincial government and around twenty simultaneous users in the university. Figure 2 shows the methodology that is followed by the surveying teams and the provincial government when the survey is performed using *gisEIEL*. The first step consists in creating and updating the information in the database using the digitalization tools. Then, the modules that perform the automatic computation of the information are used. After that, the validation task is performed and, depending on the result, the surveying teams may have to update or create new information (if there were errors), or the workflow may advance and proceed to the task of creating the database that will be sent to the Spanish government. This modules are described in more detail below.

gisEIEL allows the user to visualize the information in the database by means of map windows where the user can also edit the geographic and alphanumeric information of the different data layers. The application provides tools for the visualization, localization and edition of the geographic features as well as tools for printing maps and reports. *gisEIEL* also provides functionality for the analysis of the information, the validation of the data and the generation of the database format required by the Spanish government.

The basis of the application is gvSIG 1.0 (Generalitat Valenciana, 2008), which is an open source GIS application developed by the regional government of Valencia, in Spain. The reason for choosing this software is that it was the only one in 2007
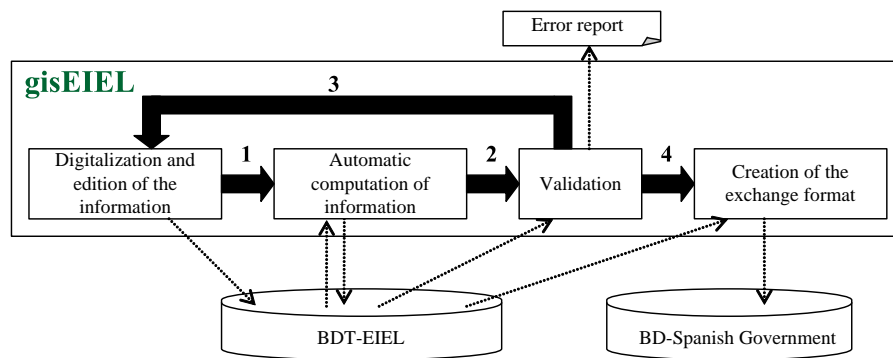
Figure 2: Survey methodology using gisEIEL.

that fulfilled the requirements of *gisEIEL*, namely: (i) reading and writing from database management systems using the Simple Features Specification for SQL standard (SFS), (ii) visualizing geographic information using different coordinate systems, (iii) supporting the edition of geographic information and (iv) including a Web Feature Service (WFS) and a Web Map Service (WMS) client.

The functionality provided by gvSIG was extended to adapt it to the specific requirements of the users of *gisEIEL*. First, a user authentication module was implemented that defines roles, permissions for each role and users associated to each role. This allows to control the operations that each individual user can perform on the system. Another improvement is that the data catalog was used to ease the way the users load the information. The usual way of loading information in gvSIG implies that the user has to set up the connection, to choose the source table and to select the columns in the table. However, in *gisEIEL*, the information in the catalog (maps and layers) is presented to the user who can load a complex map with a single mouse click. Furthermore, *gisEIEL* controls the amount of information that the user requests from the database. The application forces the user to work at a municipality level, that is, when the user starts the application, he/she selects a municipality to work with. Later on, *gisEIEL* filters all the information and displays only the information related to that municipality. This makes the application faster because the amount of information that is loaded is limited and, furthermore, it does not overload the database server nor the network. However, if the user wants to work with more than one municipality at the time, he/she can choose more than one municipality. This eases the task of connecting the geographic information in the municipality boundaries.

Regarding the digitalization of geographic information, we have developed several tools in addition to

those provided by gvSIG. *gisEIEL* supports two types of digitalization according to the type of geographic feature: *simple* and *complex digitalization*. In the case of simple digitalization, the user only has to draw a single geometry of a specific geometry type (point, line or polygon). In the case of complex digitalization, the user has to draw a set of geometries for a single feature. For instance, for a road section, the user has to draw a polygon for the surface of the road and a line for the middle line. In both cases, *gisEIEL* controls the workflow and ensures that the correct type of geometry is provided by the user. *gisEIEL* also provides many new tools to modify the geographic information stored in the database. For instance, there is a tool in *gisEIEL* to digitalize a small portion of a given geographic feature, a tool for moving and inserting vertices in a geographic feature, and a tool for splitting geographic features. With respect to geographic feature validation, *gisEIEL* can also check whether the geographic feature drawn by the user fulfils certain restrictions in order to ensure the quality of the information. These checks are used, for instance, to ensure that a given equipment (e.g: a school) is drawn within the correspondent municipality and not outside the limits, or to ensure that the water network or the road network are connected and there are no dangling nodes or surfaces. Finally, we have also improved the snapping tools of gvSIG. We have defined three new types of snapping: *snap to a vertex*, *snap to a line segment*, and *snap to a polyline*.

Finally, considering that some of the information in the survey can be derived from the raw data inserted by the surveying teams, *gisEIEL* provides functionality to automatically compute this information. For instance, the survey requires the teams to specify the elements of the water network that give service to each population entity. That is, for each population entity the user has to specify the water pipes, water tanks, treatment plants, water catchments and

all the other elements that provide a service to the entity. Instead of associating manually this information, *gisEIEL* provides functionality to perform this task automatically creating a graph for the water network and using graph exploring algorithms. Another automatic computation that *gisEIEL* includes are algorithms to compute information from the data stored in the database using spatial analysis. For example, it includes algorithms to compute the populated areas with deficit of street lights, estimations of waste production, or milestones.

5 CONCLUSIONS AND FUTURE WORK

We have described in this paper the open source geographic information system developed by the provincial geovernment of a Coruña and the Database Laboratory of the University of A Coruña. We have described the migration process from the previous GIS based on proprietary software to the current system based on open source software. We have also described the main applications of the system: *WebEIEL* and the *ideAC node*, the web applications for publishing the information in the Internet, and *gisEIEL*, the desktop application for querying and updating the information in the database. We have also presented the current effort to distribute the software and the information between the municipalities of the province.

Our work is not finished yet. We have a plan for the following years that includes the following tasks. First, we plan on including the information from previous surveys. There is historical data starting in 1988. The database includes only the current state of the survey. We plan on importing the historical data and providing tools for querying and analyzing this information. Furthermore, we must design and implement a method to store the future modifications to the database. This implies storing historic versions of the geographic features when the user updates and commits the change. Moreover, the current version of *gisEIEL* distributes the information but it is not prepared to recover the information updated by the municipalities. We plan on designing a methodology to include the information modified by the municipalities in the survey, and thus, decentralize the task of surveying. Finally, *gisEIEL* is a great tool for the municipalities to query the information in the survey, but it does not provide any tool to perform their daily tasks. We plan on including tool to manage the processes of urban planning, licenses, demography, taxes, and many other municipal management tasks.

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