WebEIEL: A WEB-BASED GIS FOR THE E.I.E.L.*

Miguel R. Luaces[1] **Nieves R. Brisaboa**[1] **Jose R. Paramá**[1] **José R. Viqueira**[2]

Databases Laboratory
Department of Computer Science
University of A Coruña
Facultade de Informática, Campus de Elviña, s/n. 15071.
A Coruña. Spain
{luaces, brisaboa, parama}@udc.es

Systems Laboratory
Department of Electronics and Computer Science
University of Santiago de Compostela
Instituto de Investigaciones Tecnológicas
Campus sur, 15782 Santiago de Compostela, Spain
joserios@usc.es

Abstract

Geographic information systems (GIS) are becoming more usual in companies and organizations due to the improved performance of computer systems. Similarly, Internet has become a common place to publish and search almost any kind of information. Therefore, these two tools were used to carry out the Survey on Infrastructure and Local Facilities (*EIEL*, from the Spanish name) by the *Excma. Diputación de A Coruña* (Provincial Council of A Coruña). These tools were also used to publish on the Internet the information collected.

In this paper, we describe the *WebEIEL* application, which is being used at the *Excma. Diputación de A Coruña* to publish the information collected by the *EIEL*. This application can be found at the following address: `http://www.dicoruna.es/webeiel/`. First, we briefly describe the workflow that was designed to collect, manage and organize the information. Then, we show the functionality of the web-based application (*WebEIEL*), and we describe in detail its system architecture, which is built using the commercial GIS development tool *Intergraph Geomedia Web Map*. We follow with an analysis of the advantages and drawbacks of using commercial GIS development tools instead of using open source components and international standards (e.g.: OpenGIS, ISO/TC 211). We end this paper with a description of our future lines of work, which include the implementation of the application with a system architecture based on open source components and international standards.

1 INTRODUCTION

Geographic information, in the form of paper maps, has been a driving force behind the progress of our society for many centuries. Until a few decades ago, manipulating, synthesizing and representing geographic information was restricted to paper maps and these tasks were limited to manual, non-interactive processes. The exponential improvement in the performance of computer-based technologies and the increasing demand for interactive manipulation and analysis of geographic information have created a need for *geographic information systems* (GIS) [1, 2, 3, 4].

Similarly, Internet has turned into a common place to publish and search almost any kind of information due to its wide-spread and versatility. Particularly, many companies, organizations and public services are using Internet to publish geographic information [5, 6].

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In order to optimize the management of the country, the Spanish territory and the government responsibilities are divided into a hierarchy of four levels. The central government deals with issues concerning the entire country, such as foreign affairs. The country is divided into nineteen autonomous regions (*Comunidad Autónoma*), each having its own government with different levels of independence. The government of an autonomous region has legislative, executive and judicial power over the areas whose competence was delegated by the central government (e.g., health care or education). Each autonomous region is further divided into a variable number of provinces (ranging from one province in the smallest ones to nine in the biggest one). Each province has its own Provincial Council (*Diputación Provincial*}) whose tasks are mainly of an administrative nature. Finally, each province is divided into a variable number of municipalities.

The Provincial Council is in charge of coordinating the work of the municipalities in the province, ensuring solidarity and balance among them. It encourages the economic development and improves living conditions in underdeveloped municipalities in order to avoid big differences between them. These goals are accomplished by realizing the following tasks:

- Ensure the correct provision of municipal services in the entire province (e.g.: social services, cultural services).
- Coordinate the services of the different municipalities among them.
- Give legal, economic and technical assistance and cooperation to municipalities, especially to those with less economic and management capacity.
- Render the public services that imply several municipalities, (e.g., water supply, sewage treatment, road maintenance).
- Take part in the coordination process between the municipal government and the regional and country governments.

In order to discover the funding needs of each municipality and to propose special action programs to balance the living conditions of the municipalities, the Provincial Council of each province need a tool to objectively analyze and evaluate the situation and state of infrastructure and equipment in each municipality. For this purpose, the national government requires every Provincial Council to conduct, every five years, a survey on local infrastructure and equipment, (named EIEL from the Spanish *Encuesta de Infraestructura y Equipamientos Locales*.

The province of A Coruña is located in north-western Spain. With more than one million inhabitants and almost eight thousand square kilometres, it is densely populated with more than a hundred and twenty-five inhabitants per square kilometre. The Provincial Council of A Coruña decided to broaden the goals of the EIEL for the year 2000. More particularly, these new goals were considered:

- Extend the information to be collected, both in terms of the different kinds of elements to be surveyed, and the amount of information for each particular item.
- Reference the items surveyed to its geographical location or extent.
- Build a geographic information system with the information collected. This system is going to be used by the Provincial Council staff. Moreover, a publicly-accessible, web-based application enables the inhabitants of the province (actually, everybody connected to the Internet) to browse the information collected.

These goals were achieved through a two-year project carried out by the University of A Coruña. A large group of students from the civil engineering school and the architecture school, supervised by a group of professors, collected the data by direct observation or interviewing the responsible staff in the municipality. At the database laboratory of the University of A Coruña, we designed and developed the applications supporting the data collection work flow. Then, we developed a geographic information system to manage and exploit these information[7, 8].

In this paper, we describe the *WebIEL* application, which is being used at the *Excma. Diputación de A Coruña* to publish the information collected by the *EIEL*. This application can be found at the following address: `http://www.dicoruna.es/webeiel/`. First, in Section 2, we briefly describe the workflow that was designed to collect, manage and organize the information. Then, we show in Section 3 the functionality of the web-based application (*WebEIEL*), and we describe in detail its system architecture, which is built using the commercial GIS development tool *Intergraph Geomedia Web Map*. We follow in Section 4 with an analysis of the advantages and drawbacks of using commercial GIS development tools instead of using open source components and international standards (e.g.: OpenGIS, ISO/TC 211, SFS [9], WFS [10], WMS [11], SLD [12]). We end this paper in Section 5 with a description of our future lines of work, which include the implementation of the application with a system architecture based on *open source* components and international standards.

2 BUILDING THE GEOGRAPHIC INFORMATION SYSTEM FOR THE EIEL

To build the GIS for the EIEL it was necessary to collect a huge amount of data of many different types. Information was collected for the 94 municipalities in the province, ranging from general information about the municipality (e.g., population) to detailed information of each village. The database contains information about 4000 towns and villages, more than 35000 road sections, more than 40000 street sections, approximately 17000 water supply pipe sections and 17000 sewage treatment pipe sections. Moreover, information about services in the municipality was collected. This includes information about 700 education centres, 1200 sport facilities, 1000 parks and gardens, 800 culture facilities, and 200 health centres. The geographic location and/or extent of more that 100 different kinds of elements was surveyed, including municipality borders, village built-up areas, road section surfaces, pipe section paths, or buildings. The database totals around three gigabytes of information.

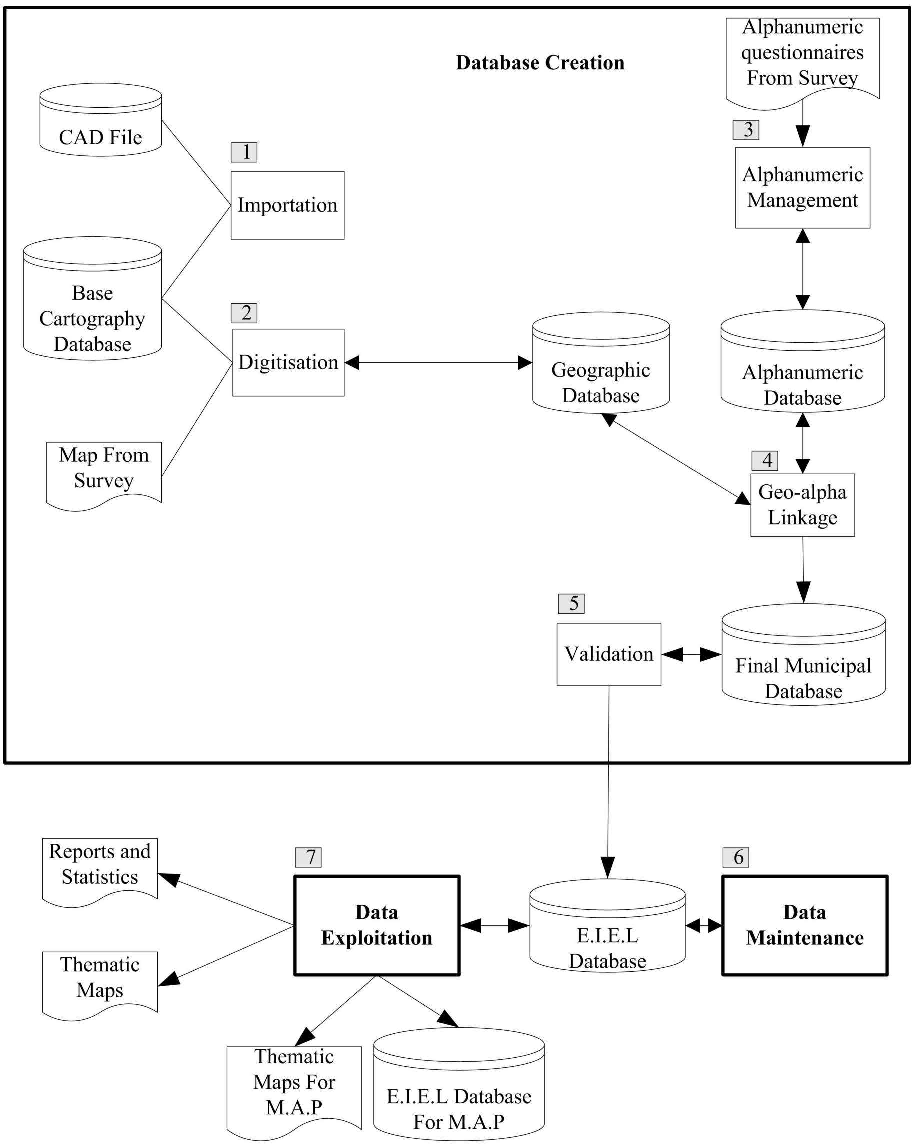

Figure 1: Development Process Workflow

Considering the vast amount of information that had to be collected to build the EIEL GIS, it was necessary to design a workflow that enables the supervisors to control the process of collecting the information, introducing the data into the database, and validating the correctness of the database. Figure 1 shows a diagram that illustrates the workflow. Three main tasks were identified (depicted as thick rectangles): the *database creation* task, the *data exploitation* task, and the *data maintenance* task. Within the database creation task, five subtasks were identified (depicted as thin rectangles).

The database creation task involved the creation of the database that stores the data collected by the survey process. The task was divided into five subtasks that were carried out concurrently, and we developed an application to support each of these tasks, namely: a *geographic data import* application (1) to import the geographic information from CAD files, a *geographic data input* application (2) to input the geographic information not present in these files, an *alphanumeric data input* application (3) to input the alphanumeric information, a *geographic-alphanumeric linkage* application (4) to link the geographic information with the alphanumeric information, and a *data validation* application (5) to check the correctness of the information before accepting it definitely.

The data maintenance task involves the updates to the database performed by the Provincial Council once the survey is completed. These updates may be caused by errors detected in the survey, or by changes in the surveyed items that require changes in the database to keep it up to date. This task is performed used the *GISEIEL* desktop application (6).

Finally, the data exploitation task involves the exploitation of the information collected by the survey. This is mainly done by generating thematic maps and statistical reports. This task is carried out by two different applications, a desktop application that is used by the Provincial Council staff called *GISEIEL* (6), and a web-based GIS that can be accessed over the Internet called *WebEIEL* (7).

This project results in a geographic information system that is a powerful analysis tool in which many different evaluation mechanisms can be used and many *indicators* were produced to analyze the living conditions in the province. The existence of geographic information attached to the alphanumeric information allows end-users to perform geographical analysis with the information. Moreover, the existence of a database with the information for the year 2000 and a set of tools for the management of this information, turns the survey of the year 2005 into a much easier task.

3 WebEIEL

This section describes in more detail the *WebEIEL* application. First, we give an idea of the functionality of the application in Section 3.1. Then, we describe the architecture of the application in Section 3.2.

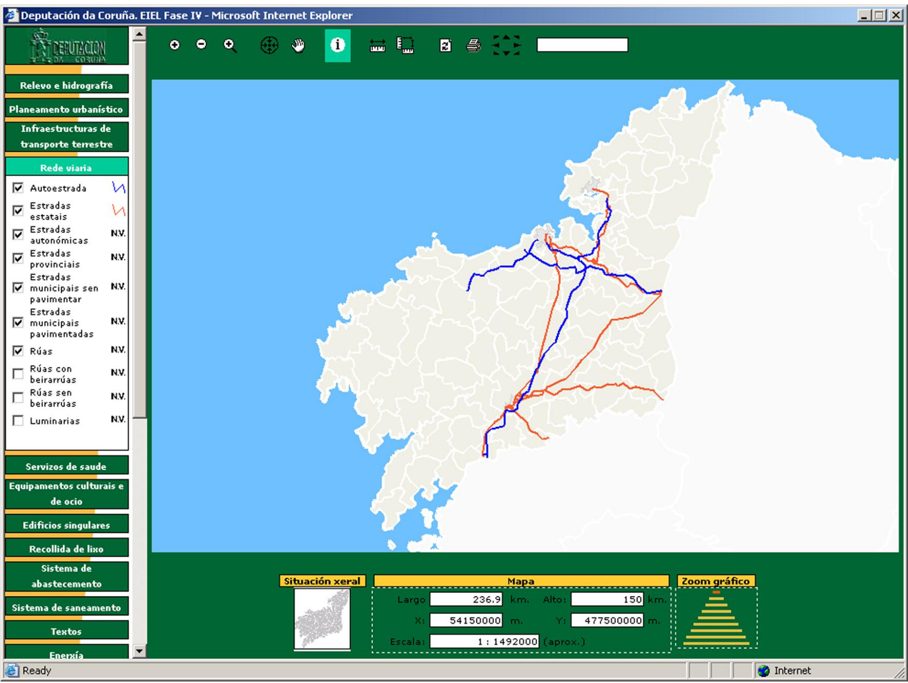

Figure 2: *WebEIEL* Map Window.

3.1 *WebEIEL Application Functionality*

The web-based GIS for the exploitation of the EIEL includes the following functionality:

- *Thematic maps*. These maps show all the information about the province using interactive thematic maps (e.g., road network, sewerage, or water supply). Users may select a given area to be displayed, and browse the information of any of the infrastructures or urban services displayed in a window similar to the one shown in Figure 2. Four different areas can be seen in this figure:
    - *Graphical legend*. It is located on the left side of the window, and it enables the user to select the information to be displayed on the map. Cartographic layers are grouped into categories to facilitate the visualization. The user can configure whether the cartographic layer must be visible or not using a check box located close to the layer name. The application performs a limited form of automatic map generalization by selecting the type and resolution of the geographic object displayed for the cartographic layer at a given map scale. The application also controls whether a cartographic layer should be visible at all at a specific map scale.
    - *Tool bar*. It is located on the upper side of the window. The user can interact with the map using the tools in this bar. Particularly, the user can *zoom*, *centre* and *pan* the map view, *get information* of a geographic feature by clicking on a point in the map, *measure* lines and rectangles in the map, *reload* the map after changing the layers that are visible, and *print* the map to a PDF file.
    - *Context information*. It is shown at the lower edge of the page, and it displays an *overview map* that shows the area of the province that is being visualized, the map width, height, centre coordinates, map scale, and a graphical representation of the zoom level that can be used to change the map scale in a visual way.
    - *Map area*. It is the central area of the window, and displays the current map. It also displays a tool tip with information of the geographic features when the mouse is moved over the geographic objects.

The map tools and the graphical legend allow the user to build a customized view of the information, to print this view, and to retrieve information of the displayed objects. Figure 3 shows an example of a map window customized.

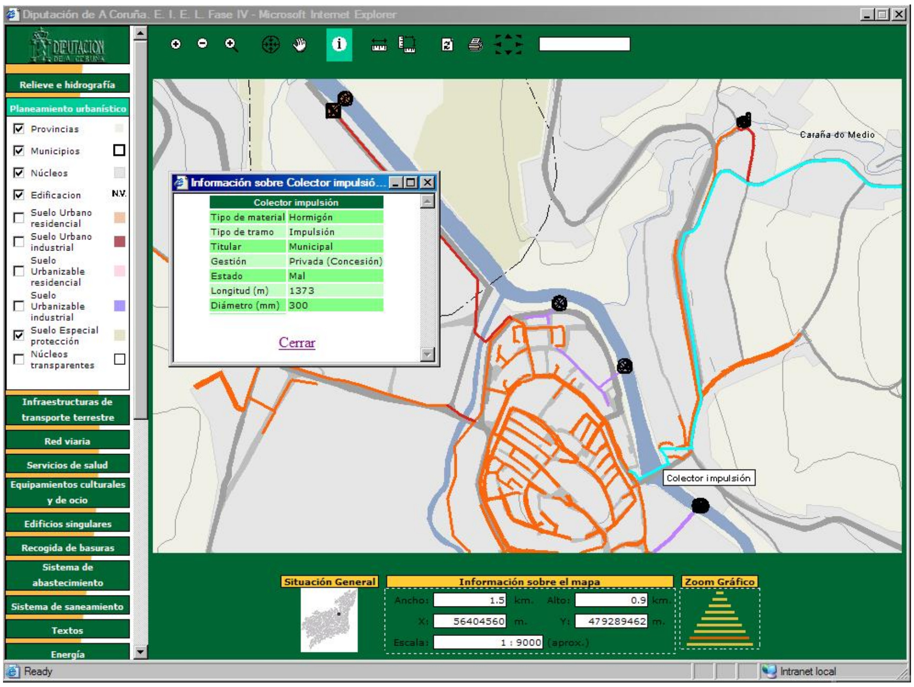

Figure 3: *WebEIEL* Map Navigation

- *Synthetic maps*. These maps display a choropleth map of the state of the service in the municipalities of province, using the different synthetic indicators defined by the Spanish Ministry of Public Administrations. The application shows a window similar to the one shown in Figure 4. The actual value of the indicator for each municipality is displayed when the user moves the mouse over the map.

- *Report generation*. In addition to maps, the application also generates reports with the information stored in the system.

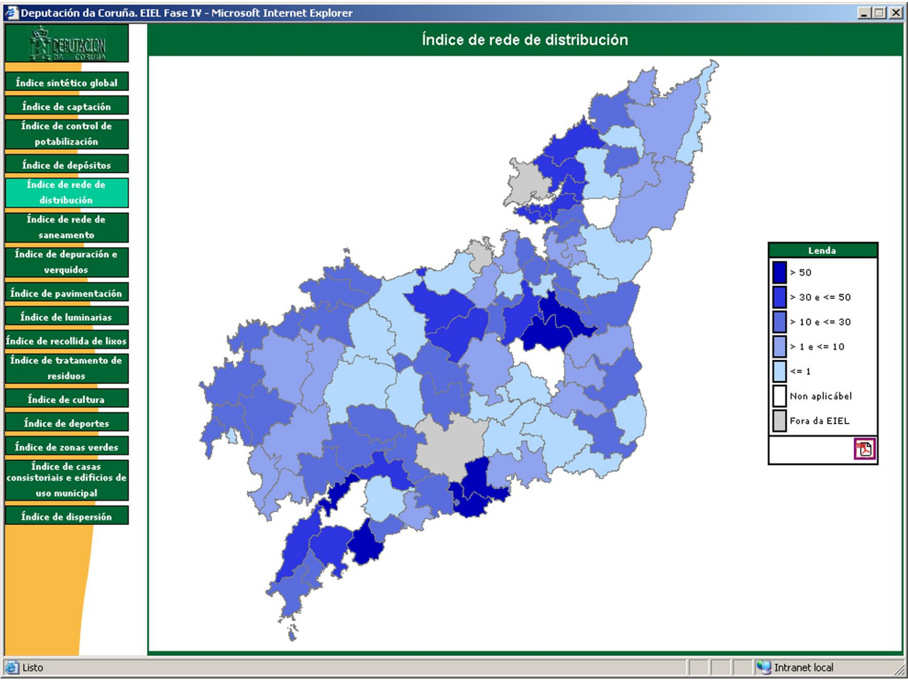

Figure 4: *WebEIEL* Synthetic Map Window

3.2 System Architecture

Figure 5 shows the system architecture of *WebEIEL*. The components that we had to develop are shown with a grey background, whereas the commercial components are shown with a white background. The dashed lines represent the separation of the tiers of the architecture. The system is web-based, and therefore the functionality is structured using a client-server architecture.

On the server side, the information is managed by a relational DBMS (Microsoft SQL Server 7.0). The geographic information is managed by Intergraph Geomedia Web Map, which follows the opaque relational approach using BLOB attributes in the relations to store the geographic values. The *activity module*, and the *style and generalization module* had to be developed particularly for this application because the ones provided by Intergraph Geomedia Web Map were not sufficient to meet our requirements. Finally, the information of the web application is served by Microsoft Internet Information Server, the web server supplied by Microsoft, which was chosen because it is required by Intergraph Geomedia Web Map.

The client side of *WebEIEL* was implemented using dynamic HTML, that is, web pages with scripts implemented in Javascript to provide client-side functionality. The map image is displayed by a map display plug-in embedded in the web page. This plug-in was developed by Intergraph, and it is a Java applet that displays the map image, and implements many presentation functionality such as the computation of distances and areas. Therefore, the *WebEIEL* application uses a *thick-client* approach. The main reasons for choosing a thick-client approach for the client were these:

- A thick-client approach makes it easier to provide the user with some interactive functionality. In our particular case, we wanted the application to display a tool tip message when the mouse is over a geographic object to identify the geographic feature. This is not an easy task to do using only dynamic HTML, but it is much easier when a thick-client is used.

- To display the map using a vector image format that provides a much higher quality than raster image formats. There is no native support for vector image formats in web browsers, and therefore, a thick-client is needed.

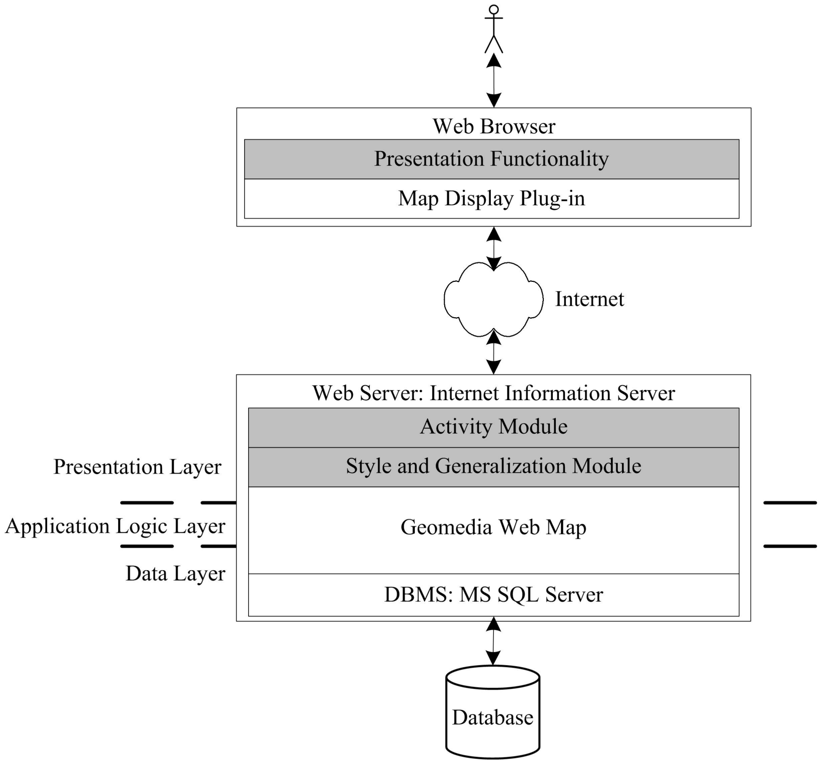

Figure 5: System Architecture for the *WebEIEL*.

4 COMPARISON WITH A STANDARDS-BASED ALTERNATIVE

The *WebEIEL* application was implemented using Intergraph Geomedia Web Map instead of an alternative based on international standards and open source components due to the following reasons:

- *Time and cost restrictions*. Special 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.

- *Lack of maturity in standards and components*. When the analysis and design for the application started, neither the international standards were mature, nor the open source components had the functionality we needed.

The main difference between the application architecture and the architecture of a standards-based application is that in the latter the tiers of our architecture are completely independent they only interact at the interfaces. Whereas, the functionality of the tiers in the *WebEIEL* application is implemented using Intergraph Geomedia Web Map using a single monolithic software module.

The other big difference is that the functionality not implemented by the commercial Intergraph Geomedia Web Map had to be implemented using an additional software tier on top of the product, as shown in Figure 5. These differences cause the following problems in the *WebEIEL* application:

- *Flexibility*. The architecture of the application cannot easily accommodate changes in the requirements. The functionality of the architecture is often implemented in a single module with proprietary interfaces that are highly-interdependent between them. Therefore, it is not possible to change only parts of the system, when the requirements vary, or to use third-party modules for specific problems.

- *Reusability*. Given that GIS development tools often define proprietary interfaces to access their functionality, custom-developed modules for a GIS application implemented using a GIS development tool cannot be used with an application developed using a different GIS development tool. This is because the modules are forced to use the proprietary interfaces, which are not present in other GIS development tools. Similarly, the information storage format is usually a proprietary one. The result is that the application is too heavily integrated with the technology and cannot be ported to other software platforms.

- *Efficiency problems*. Given that the functionality of the application has been implemented by the commercial product using a monolithic module, additional modules cannot be integrated at the appropriate place in the architecture. On the other hand, using open source components, additional functionality can be added by the developer at the place where it is more efficient.

These problems are common to many GIS development tools. Traditionally, the main interest of vendors of GIS development tools has been to offer additional functionality as fast as possible, and to capture clients in such a way that they cannot switch to competitors. Building interoperable systems has not been a major concern until a few years ago. Nowadays, the vendors of GIS development tools are realizing that users and developers prefer open and modular tools over closed and monolithic ones.

5 CONCLUSIONS AND FUTURE WORK

In this paper, we have described the *WebIEL* application, which is being used at the *Excma. Diputación de A Coruña* to publish the information collected by the *EIEL*. This application can be found at the following address: `http://www.dicoruna.es/webeiel/`. We have also analysed the advantages and drawbacks of using commercial GIS development tools instead of using open source components and international standards (e.g.: OpenGIS, ISO/TC 211).

Summarizing, by using a GIS development tool that implements the functionality using a monolithic software module instead of using independent components based on standards causes the application to be too heavily integrated with the technology. It is extremely difficult to integrate functionality from other GIS development tools, or to reuse the functionality of the *WebEIEL* application in other development projects.

As future work, we have started working on the implementation of the *GISEIEL* and *WebEIEL* applications using standard-based, open source components. For this implementation, we are using the architecture proposed in [13, 14].

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BIOGRAPHIES

Miguel R. Luaces received his M.S. degree in Computer Science from the University of A Coruña (Spain) in 1998 and a Ph.D in Computer Science from the University of A Coruña (Spain) in 2004. He undertook research in the area of spatial, temporal and spatio-temporal databases at the FernUniversität Hagen (Germany) under the ChoroChronos project funded by the European Union. He is currently a member of the Databases Laboratory of the University of A Coruña where he has been involved successfully in a number of research and development projects, and a lecturer at the same University. His research interests include Geographic Information Systems, Software Engineering, Spatial and Spatio-temporal Databases and Web-based Information Systems.

Nieves R. Brisaboa received her M.S. degree in Psychology in 1979 from the University of Alcalá de Henares (Madrid). In 1992 she received the M.S. degree in Computer Science from the University of A Coruña. She received the PhD in Psychology (1994) and Computer Science (1996) from the University of Santiago de Compostela and the University of A Coruña, respectively. Today, she is an associate professor at the University of A Coruña and director of the Databases Laboratory from this University. She has authored many publications in international journals and conferences. Her research interests include Deductive Databases, Document Databases (working on the field of Digital Libraries, Database Federation, Text Retrieval, and Web Databases), Data Mining, Software Engineering, Artificial Inteligence, and Geographic Information Systems.

José R. Paramá obtained his Master in Computer Science in 1994 by the University of A Coruña. His PhD studies were founded by the local government of Galicia (Spain) with several grants until 2001, when he got his PhD by the University of A Coruña as well. Currently he is a lecturer in the same university. His topics of interest are text retrieval, text compression and spatial databases.

Jose R. Rios Viqueira received his first 5-years degree in Computer Science (University of A Coruña, Spain, 1998) and a Ph.D (Computer Science Department, University of A Coruña, Spain, 2003). He was an active researcher in the CHOROCHRONOS TMR project that was funded by the European Union, where he undertook research in the area of spatial, temporal and spatio-temporal databases. He has been involved successfully in a number of research and development projects funded by the public administration of Galicia (Spain), the Spanish Government and the European Union. He acts as reviewer in journals and conferences. Today he is a lecturer at the Department of Electronics and Computer Science, University of Santiago de Compostela. He is also a member of the Databases Laboratory of the Department of Computer Science, University of A Coruña. His research interests include Geographic Information Systems, Spatial and Spatio-temporal Databases and Web-based Software Architectures.