Modeling and Development of a WebGIS for environmental monitoring of coastal areas that are influenced by the oil industry

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ABSTRACT

Coastal areas are strongly modified due the own natural factors, such as direction and speed of the marine currents, height of the waves, level of the tides, action of the winds, among others. These elements can affect the morphologic structure of an area, because they are the main responsible for the erosion / deposition of sediments. The Guamaré area is situated in the north portion of the state of Rio Grande do Norte, it is marked strongly by depositionals and erosions coastal processes caused by the united action of the winds, currents, waves and tides. It is an area with high coastal dynamics, being constantly modified by the coastal parameters. The case study used in this work was the area of Guamaré, located in the northern portion of Rio Grande do Norte, northeastern Brazil. In this area there is the Guamaré Pole Petroleum, the largest onshore oil producer in Brazil, which makes the area highly susceptible to accidental spillage of oil. Besides the erosion occurs in the region for socio-economic conflicts, besides the action of the oil industry, there is also a strong trend towards the expansion of shrimp farming, as the interest shown by business sector to occupy areas formerly used for salt extraction. Another important aspect is the development of economic activities in the vicinity of riverbeds components of watersheds. WebGIS technology is particularly interesting for the dissemination of the geographical information and its variations. The main objective of this study was to model and develop a WebGIS based on a spatio-temporal database to analyze and assess areas that are influenced by the oil industry and in need of environmental management. The applied methodology followed a sequence of steps: collection of data that would be inserted in WebGIS, development of the conceptual, logical and physical models, development of a spatio-temporal database and a Web system which access this database, access to the WebGIS via internet. With this WebGIS is possible to analyze the changes occurring in the coastal area Guamaré from 2000 until the present day. It’s possible to see a noticeable devastation of area for shrimp farming, salt and oil exploration. Guamaré is an area affected and in need of a continuous monitoring.

ADDITIONAL INDEX WORDS: WebGIS, oil industry, environmental monitoring.

INTRODUCTION

Coastal areas are heavily modified due to the very natural factors such as direction and speed of ocean currents, wave heights, tidal level, and the wind, among others. These elements can affect the morphological structure of an area, since they are primarily responsible for erosion / deposition of sediments. The area of Guamaré, located in the northern portion of Rio Grande do Norte, northeastern Brazil, is strongly marked by depositional coastal processes and erosion caused by joint action of winds, currents, waves and tides. It is an area with high coastal dynamics, being constantly modified by coastal parameters (Grigio et al., 2009).

The case study used in this work was the area of Guamaré (Figure 1), located in the northern portion of Rio Grande do Norte, northeastern Brazil. This region is strongly marked by depositional coastal processes and erosion caused by joint action of winds, currents, waves, and tides. It is an area with high energy coastal dynamics, being constantly modified by coastal parameters. In this area is located the Pole of Guamaré Petroleum, the largest onshore oil producer in Brazil, which makes the area highly susceptible to accidental spillage of oil.

Besides the erosion, the region suffers of socio-economic conflicts and the action of the oil industry, there is also a strong trend towards the expansion of shrimp farming, as indicated by the interest shown by the business sector to occupy areas formerly used for salt extraction. Another important aspect is the development of economic activities in the vicinity of riverbeds components of watersheds.

Currently coastal activities suffer the constant economic pressure for efficiency, a very strong social pressure, demanding the companies to have an “environmentally friendly” stance. In this context, geospatial technologies can play an important role in...
environmental monitoring in coastal areas. The term monitoring is being employed here in order to follow in time, to detect, analyze, map and quantify possible changes to be represented spatially.

Thus, the appropriate use of computer models, with databases and specific protocols for manipulation of thematic maps and satellite images, and other technologies such as GIS have helped the environmental professionals to diagnose the area and make automation and prognosis of environmental conditions in cases of oil spills. The new markets of Internet have been cited as a major reason for the current expansion of GIS and its use in various domains, making GIS a means of communication to provide information and knowledge to the public (Yang et al., 2004). The role of WebGIS is to remove these significant impediments to effective use of GIS. The goal is that users can be more productive in the application of GIS technologies, eliminating the time spent in handling software and data collection. The WebGIS allows the user to request a service, which includes data and analysis tools, from anywhere using the Internet.

The WebGIS of Geographic Information Systems can be defined as a set of geographic information services for the Internet, based on a network that uses different forms of Internet access to provide geographic information, analytical tools and different GIS services (Peng and Tsou, 2003). The availability and dissemination of issues dynamically over the Internet via the WebGIS, allows integrating, disseminating and communicating geographic information visually on the Internet.

With the WebGIS it is possible to generate dynamic pages that allow the user more objective queries exclusively devoted to topics of interest (Mangabeira et al., 2002). The WebGIS combines two powerful technologies: GIS and the Internet, providing connectivity at the global level. The result of this synergy results in greater ease in finding data, share analytical tools and the fact they both reach a larger number of users (Tang and Selwood, 2003).

**METHODS**

**Computational Technologies Used**

The main computational technologies used to develop the WebGIS proposed in this work were: the management system PostgreSQL database with its spatial extent Postgis and the map viewer MapServer. PostgreSQL is an object relational database manangement, developed as free software. The PostGIS is a spatial extension of PostgreSQL. It can be defined as a geographic database that stores the spatial data and is integrated with POSTGRELSQL (Buehler and Mckee, 2007).

To develop a system that accesses the database, and visualize the maps that support a decision-making, it was necessary to combine computer technologies mentioned above. Thus, the unification and interoperability of these technologies allowed to develop the Database Space-Time, which would give full support to the Space-Time WebGIS.

The database was developed in the PostgreSQL also using its spatial extension PostGIS. The data entered and the consultations done were carried out using SQL commands and SQL Spatial. The MapServer permitted to view the spatial data stored in the database, always available on the Web, using the Apache server. All programming involved, ranging from the insertion of data into the database and its display was done in SQL, Spatial SQL, PHP and MapScript.

**Applied Methodology**

First, the geographical, geological, geomorphological, and hydrodynamic data, among others, were collected to enable an environmental analysis of the area. These data were collected by Grigio et al. (2009) and Souto et al. (2004) intending to store all the data in the space-time database. After collecting data from field work, they were converted and processed to be used in developing software for decision support.

Next, space-time database conceptual, logical, and physical models were performed. The GeoFrame-T conceptual model was used (Figure 2).

**Figure 2. Conceptual Model database of Guamaré area.**

After having decided which data would be stored and how they would be stored finally one came at the time to develop the database computationally, and to enter all necessary information on one’s computer. The first step was to insert the selected data from each study area in POSTGRESQL database, also using its spatial extension PostGIS.

The meteorological data (winds), hydrodynamic data (waves and currents), and dunes were stored in textual form of tables, only with alphanumeric fields with no spatial representation. To enter this information on PostgreSQL, we used normal SQL commands of creation and entering data, as with any conventional database. Data regarding Satellite Images and Aerial Photographs are treated as files and stored in places that can be accessed by the system. Thus, whenever the user requests to view a photo and / or an image, the system itself displays what was required. To achieve this, regular tables were created via SQL, and there is a column that is the link to the location where the photo or image is stored.
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To store the thematic maps it was necessary to use PostGIS as it is able to manipulate spatial data. Thematic maps are presented in the ESRI extensions: .SHP, .SHX and .DBF, being SHP the most important for the display, since it refers to spatial representation of the map. To migrate this data format to the format of ESRI PostGIS, it is necessary to use a converter that achieves this interoperability. To load data in PostGIS, it should have data in the format Shp (also known as shapefile) and use the converter.

RESULTS

The developed system is easy to be handled with a friendly interface and simple to understand. The services implemented in the system are conducted via web browser. Assuming the user wishes to view the data from the city of Guamaré, he must select that city found in the layer in the legend. As defined in the conceptual model chosen and the data stored by that municipality are listed. Therefore, the system shows the user what data Guamaré existing in the database and if he chooses to analyze.

After the user selects the data he wants to see, the system offers a result of the request. If meteorological data (winds) and / or hydrodynamic data (waves and currents) are selected, they are displayed in the map collection point them in addition to a data table with their main information. In Figure 3 it is possible to see the photo galinhos01.jpg.

Another great advantage of this system is the possibility of space-time queries of some data stored in the database. Such consultations are held on the second page of the site. The areas that are possible to perform this type of consultation are of Galinhos, Guamaré and Sao Bento do Norte cities.

To choose one of three areas in the query screen of the system, the user must open the options of the desired area and select what type of data he wants to query perform space-time.

It is in the area Guamaré that the system is outstanding. Selecting this area, you can view and analyze the spatial-temporal variation of the use and occupation of land between the years 1989, 1996 and 2001, data collected by these Grigio (2009).

The user must now select which (s) feature (s) as he wants to perform the query space-time. Assuming that the mangrove was selected item to be assessed and analyzed during the years 1989 and 1996. The result of this query appears in Figure 4.

The caption on the left side of the map-result helps to understand it. Through this consultation and review, the year 1989 is represented by green areas and the year 1996 is represented by the red line. It has become the standard to improve the projection of one year on the other and evaluate changes or not. In this case the swamp, it is apparent that this has changed from 1989 to 1996. The area of this feature decreased in seven years and by visualizing the result with the system, one reaches the conclusion that this area was very Guamaré devastated over this period (over 3,000 km²), which should have caused an environmental impact considerable in this region. It is for environmental professionals, after consulting the system and give the changes in the field, taking steps to ensure that this area does not continue to be so heavily devastated by salt and shrimp farming in this region.
Performing another query to the system, the aim now is to evaluate changes in the features of Guamaré between 1996 and 2001. Suppose you want to evaluate the area of pasture between these two years. The result of this query appears in Figure 5.

When analyzing the results of this query-screen, one sees that the area of pasture increased over those five years, meaning that places have been devastated for that to happen. There was an increase of 6000 km$^2$ of grasslands, equivalent to a 27% increase in area.

The system can be considered a support system for decision making with regard to the area Guamaré since that displays all the spatial and temporal changes or not suffered by the main features of the area (mangrove, scrub, salt, oil hub, among others). Practitioners in the area of environmental monitoring, a system is invaluable. Since querying the system and analyzing their results, it is possible to make arrangements for environmental preservation, monitoring and/or remediation. For example, a mangrove much deteriorated over the years requires attention in future activities in the area of salt fields and shrimp, as these are characterized by highly degraded mangrove regions.

Figure 4. Outcome of consultation on the mangrove area Guamaré between the years 1989 and 1996.

CONCLUSIONS

The computer system has developed all the technological facilities needed to meet the demands of environmental monitoring projects and be available via the web. It is a system capable of accessing spatial data available in its database, which allows the analysis of these data for different seasons and presents qualitative and quantitative development of sectors with the passage of time. The comparative result is presented in the form of digital map and also on how much has been lost or rescued in the area in a given sector. This simulation of situations that analyze the past helps us understand the present and subsidizes forecasts of future events.

This strategic approach in modeling the real world has enabled the development of computational systems that can assist in making operational decisions on crucial issues that need reliable and valid. Environmental monitoring of areas at risk arising from the activities of the oil industry is one of the fields of research that may be worth a lot of these types of system.
LITERATURE CITED


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Figure 5. Result of the space-time query in the area of pasture Guamaré, between the years 1996 and 2001.