

Geographic Information System (GIS) For Geospatial Data Management and Analysis Based on Open-Source Technologies

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Abstract— Even with the increase in need of Web-GIS for various applications in planning, there are not many platforms providing proper functionalities required. Using Open-source technologies for development can make the software cost effective, reliable and flexible. This Web-app is implemented using open-source tools such as GeoServer, PostGIS and Openlayers for visualization and updation of geo-spatial data.

Index Terms— Web-GIS, Geospatial Data, GeoServer, PostGIS, OpenLayers.

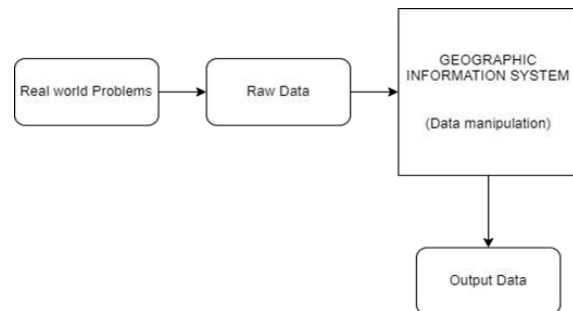
I. INTRODUCTION

Geographic Information Systems is a field in Information Technology which provides numerous applications in various domains. It is used to visualize and analyze geospatial data. It is used to share expertise and knowledge regarding natural resources, disasters, geographical observation and is also used in urban and town planning.

Geographic information systems are widely used in planning deployment of community services and city planning. There are various commercial applications which are currently used for town planning and urban planning which are quite expensive. Although free and open-source applications are also available, the difference between a paid and a free-to-use application is quite apparent. So, we aim to build an application which will be free and open source and more service oriented which means anyone can use its services whenever required, free of cost.

Thousands of organizations use GIS to visualize, analyze and interpret geo spatial data to solve complex world problems and analyze patterns and derive a solution accordingly. GIS is attached to

various fields of studies like engineering, manufacturing, telecommunications and planning. The development of the Geographic information system started in mid 1960, today GIS is used in various sectors like education, public safety, urban planning, road planning, transportation, sustainability as well as in real estate.



The above diagram represents how raw data is sent to the data model and the data is furthermore manipulated in the GIS system and output is generated.

II. ARCHITECTURE OF WEB GIS

The architecture of WEB-GIS which has three basic components which are Client Layer, GIS Layer and Geoserver.

A. Client Layer

This component allows users to interact with the Web-app and also provides display of spatial data. Internet Browsers can perform request/response HTTP actions for the same.

B. GIS Layer

This component includes all the functionalities or services provided by the Web-app. And also is a

necessary structure for User management. The functionalities are such as

1. Displaying Raster and Vector Data
2. Spatial Analysis
3. Geo Coding
4. Geo Tagging
5. Geo Fencing
6. Route Finding

C. GeoServer

This layer is dedicated to the organization and management of spatial data and maintaining the system. For this, many web services are used here. A web service is a non proprietary standard for function calls across the internet. OGC (Open Geospatial Consortium) include –

1. WFS (Web Feature Service) - It outputs Vector data generally using some XML standards. This service is suitable for highlighting regions of a map and displaying attribute information.
2. WMS (Web Mapping Service) - It renders Raster and Vector data as map images. It is suitable to display maps on a device with limited processing power. Retrieving ready-made images from a WMS server is faster and more efficient than rendering raster and vector data on the user/client side.
3. WCS (Web Coverage Service) -It is used in retrieval of coverage (raster data set) and is web-based.
4. WPS (Web Processing Service) - WPS is an extension which is used in geospatial processing and calculations. It is basically an analysis tool for geospatial data.

III. TECHNOLOGIES

The Web-GIS application is built using open source tools to make it free and service oriented. They are –

A. OpenLayers -

It is a completely free, Open Source JavaScript Library. It is fast and mobile ready, and can be used to build lightweight custom profiles with only the components we need. It can readily be connected with other APIS and is also very convenient to customize. It enables embedding a dynamic map in any webpage very easily. Adding dynamic maps on

web pages is simplified due to this. It can show map tiles and also vector data. OpenLayers was created to encourage the usage of all types of geographic data.

It's an Open Source JavaScript that's entirely free and provided under the BSD License's two clauses (also known as the FreeBSD).

It also provides features such as

- Tilted Layers
- Vector Layers
- Easy to Customize and extend
- Cutting Edge, Fast and Mobile Ready

It can also visualize markers from many different sources making it extremely useful.

B. Geo Server -

GeoServer is an open-source server based in Java which is used to edit, manage and maintain geospatial data. Openlayers is a library like Leaflet in javascript that is used to render maps on web pages. This powerful open-source library is integrated in GeoServer which makes map rendering and generation faster and easier. The main focus of the application is its simplicity and hence this is an important tool.

It is also designed for interoperability. Many products and softwares should be able to utilize it. There should be no barriers from the most basic platforms such as Operating Systems to the more advanced ones such as Web Browsers. Publishing major spatial data sources using open standards is also a requirement incorporated personally during the design of this application. Geoserver produces high quality maps and handles multiple layers. Thousands of layers of maps are easily maintained.

GeoServer is a simple way to link existing data to virtual globes like Google Earth and NASA World Wind, as well as web-based maps like Google Maps and Windows Live Local. The Open Geospatial Consortium's Web Feature Service standard is implemented by GeoServer, which also implements the Web Map Service and Web Coverage Service standards.

C. PostgreSQL -

A very reliable and robust tool for data storage is the open source relational database management system called 'PostgreSQL' or 'Postgres'. It is known for its capable architecture and reliability. PostgreSQL is not controlled by any single company, such as many other open source programs and also has a global community of developers and companies to develop it. PostgreSQL is also completely free to use even commercially because it was released under the OSI-approved license which is a very cost-effective solution for businesses. PostgreSQL also maintains data integrity and has a very robust feature set.

IV. FUNCTIONALITIES

The functionalities provided by the application

A. Display of Raster and Vector Data

1. Raster Data - Pixels, the smallest unit of display, carry significant information when it comes to maps. Each pixel contains information about a particular geographic location. Raster data is any such pixelated data. The raster is similar to a digital image, photographs that we take from our phones or cameras in the form of pixels, the main difference being the spatial information that are present with the geospatial rasters that connect the data to a particular location.

The most prominent feature or phenomenon in the region covered by the cell is generally reflected in the cell in raster data, whereas vector data defines or identifies characteristics individually. Raster data is the optimum choice when the major focus is the locational correlations of the phenomena represented by geographic features rather than the characteristics themselves.

2. Vector Data - The vector model uses points, lines, and polygons to represent the location and shape of geographic features (as well as surfaces and volumes for 3D data), with their various aspects represented as attributes. It's typically used to keep track of discrete features like roadways and city blocks. Features are the items in a vector dataset that contain data that describes their location and attributes.

B. Spatial Analysis

Spatial analysis is a method for modeling issues spatially/geographically, computing outcomes, and then exploring and examining those findings. This sort of analysis has been shown to be extremely useful for determining the geographic appropriateness of certain areas for specific objectives, calculating and forecasting results, analyzing and comprehending change, and identifying essential patterns buried in your data.

C. Geocoding Service

When we note a particular address on a geographic map, we do not save the image of the map directly because it is not feasible to store a snapshot or screenshot of the entire address. To save such addresses we convert its location into its corresponding latitude and longitude on earth. This is called geocoding of the address. Similarly reverse geocoding is the exact opposite. Whilst receiving the latitude and longitude of an address we cannot humanly visualize it so these coordinates (latitudes and longitudes) are converted to their respective addresses. Basically like taking locations from a map and identifying their locations.

Geocoding is a key in enterprises where high-end quality addresses data is needed to provide geographic information and hence is preferred by many GIS professionals & data analysts

The process of converting a particular location's address shown on a map to geographic coordinates like latitude and longitude is called Geocoding.

Reverse Geocoding on the other hand is the conversion of given geographic coordinates in latitude and longitude to the description of the location like an address. In layman terms, showing a given coordinate marker on a map or giving a humanly readable address using given coordinates is Reverse Geocoding.

These processes can be achieved through various APIs, the most popular and best performing of which is Google's geocoding API.

Using this service, users can point to any location and get its address with their particular geographic coordinates.

D. Geotagging Service -

Geotagging is the processing of marking/tagging an area with our information. Areas can be tagged based on their vegetation, weather, wildlife etc. We can also tag shops, malls, schools and basically any landmark.

The process of geotagging involves the user dropping a marker on the map over a desired location. This marker is then appended with information for example- I want to tag a road intersection where a calamity such as a landslide or even a major accident has occurred. I will then drop a point at that location on the map and then describe the point saying - "Landslide. The road is blocked in this region".

This information is then saved in the database and everyone using the application can see that particular tag on their screens and tapping on the marker will reveal the message we had associated with it. Only the creator can edit the message and delete the marker.

E. Route Finding -

Finding the shortest route between two points using APIs. This can be used to find the distance between the current location and a marker or two markers specified by the user.

F. Geofencing Service -

Geofencing is having virtual fences on a map. An area of the map is marked using free-hand shapes or polygons such as squares, triangles, and even circles. This is the fictional boundary created in the application and it does not exist in the real world. This feature of marking the land can be used to mark regions affected by a natural calamity, regions not suitable for agriculture, regions that are not permitted to have buildings and other structures to be built on them, or simply just any boundary desired.

Assuming a use-case where a boundary is marked around an area struck by a natural calamity such as a

landslide. The live location of the user is tracked. When the user enters the corresponding virtual area, an event is triggered which might be a notification on the user's device. This tells the user that they have entered the "restricted zone" and actions need to be taken accordingly.

This feature can be used effectively in construction, land surveying and town planning.

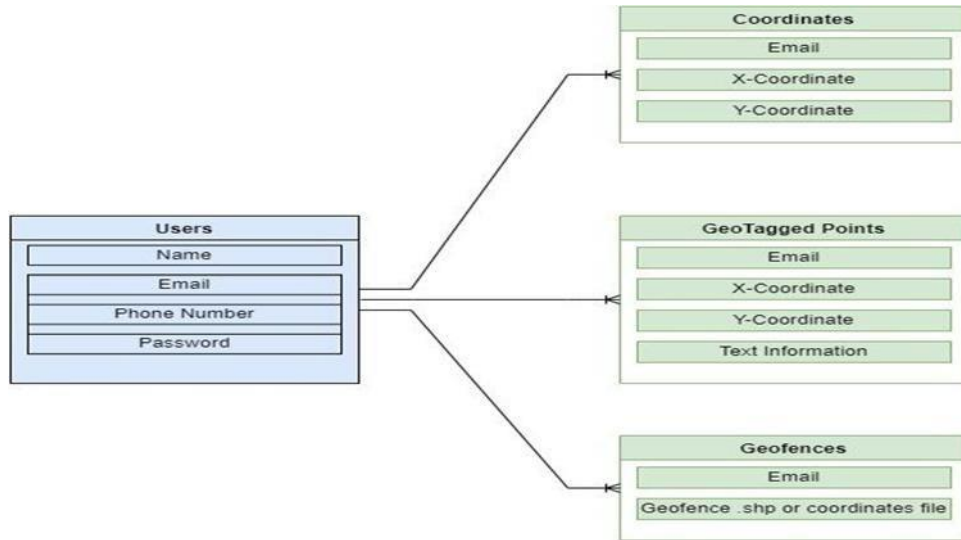
When a user enters or exits the virtual boundary (Geo Fence) with their mobile devices or also some RFID tag, an application or other software comes into play. That software will trigger an event such as a text or email or an advertisement or simply a notification using radio frequency identification (RFID), Wi-Fi/Internet, GPS, or any other internet providing service.

V. DATABASE

The database that is optimal for this application is PostgreSQL because it allows storage of shape files and other important raster and vector data files easily. The architecture of the application is simple and it is as the user needs to register first and then log in to the application. The user needs to provide a username, email address, phone number and a password. The purpose of the phone number is to send SMS alerts for geofencing services when the application is expanded in the future.

The user can then save points and lines and polygons on the map to their name which will be their own and not overridable by anyone but the user themselves. This means the database should contain one table which contains the information of the users and at least one more table containing say coordinates of points, .shp files, information in geotagged places etc which are linked to the original table via a foreign key which can be set as the email address because it is unique and not null for every user.

Here is a rough diagram of the database –



The ER diagram above shows a one-to-many relationship wherein one user can have multiple points, fences, tags etc. These will only be editable to the user who creates them.

CONCLUSION

Geographic information system (GIS) is one of the best approaches to manage applications that are relevant to geographic study such as town planning and road/ track mapping. Its feature is to collect, store, visualize, analyze and report spatial data. Urban planning, Road planning, Transportation planning and also mapping are the various functions that a GIS can perform. All the technological advancement has significantly enhanced GIS and has a vast scope in the future.

This paper described the Mapping technologies, Database standards, Web-application development standards that are relevant to the development of web GIS applications and most importantly, geofencing and how it can be used in various important domains.

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