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Online geospatial transaction system using open source libraries

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Abstract: Geospatial Information System (GIS) plays a very significant role in our daily life. In India, GIS establishments have massive databases of geospatial data. However, for appropriate planning and development activities, the digital vector data requires improvement in spatial accuracy. Inaccuracies in geospatial data exist due to various reasons such as anomalies in digital conversion processes. Under *Pradhan Mantri Gram Sadak Yojana* (PMGSY) National GIS, a reliable national level geospatial database is created. Nevertheless, achieving the spatial accuracy for so many spatial layers in short duration is a herculean task. A web-based geospatial data editing application is, therefore, designed and developed using open source software, which could initially be implemented for PMGSY. The application can access base maps from external sources like the Indian Space Research Organisation's (ISRO) Bhuvan and OpenStreetMap; the existing spatial features can be modified and new features be added. With the right data and software, geospatial data services can be used by authorised users for other projects. In future, rather than hunting for reliable digital spatial data, the officials can focus on analysis, planning, modeling, etc. The architectural framework and the application can be extended to other national GIS applications or to a national geospatial framework.

Keywords: geospatial transaction, Web GIS, WFS, open source, geospatial framework, PMGSY

1. Introduction

Geographic Information System (GIS) is enriched with spatial data that help in analyzing the associated features on spatial relations, geometry and visualization as dynamic maps. Reasonably accurate geospatial data is essential for planning, development and timely decision-making activities by the government or by anyone dealing with spatial data. Inaccurate geospatial data severely affect planning and development activities and may even result in disputes. One of the major reasons for GIS project failure is the unavailability of reasonably accurate data (Sajeevan, 2017a). The applications of spatially accurate geospatial data are innumerable; be it finding nearest election polling station, identifying precise locations of military targets, number of households and their spatial distribution in a village, locating a ship and its trajectory, coverage of forests along a road, optimum distribution of road network for handling smooth vehicle movement, emergency response, etc. The geospatial data gaps need to be filled at the earliest to cope up with the fast pace of nation building.

On analyzing completed GIS projects, it was observed that the spatial features such as district boundary, road and settlements are displaced on the digital map (Sajeevan, 2017b). It is crucial that a feature is placed on the map at the same location where it is spatially located on the ground. Looking at the trend, it may be observed that a good part of a GIS project time is spent on creating digital base data rather than getting into meaningful spatial analysis. While certain projects struggle to get reasonably accurate digital spatial data, many private agencies own and operate with relatively higher accuracy geospatial data, such as the data for vehicle navigation systems (Sajeevan, 2017b).

The major reason for spatial inaccuracy in digital data is due to the incorrect procedures adopted for data conversion process. Overlaying spatial data from different sources clearly reveals any positional shifts, which would have crept in due to inappropriate data conversion process. Figure 1 shows visible shift between satellite data and vector layer overlays on ISRO's Bhuvan (Bhuvan, 2017). Regarding Bhuvan, our experiments show that the satellite data is placed with pretty good accuracy compared with locations from Global Positioning System (GPS) and Google maps data. The inaccuracy in vector layers is assumed to be due to digital conversion issues of data that are compiled under different projects by different agencies. Similar inaccuracies are observed on other Web GIS applications as well. The spatial mismatch of data from different sources is a common trouble faced by the GIS industry (Sajeevan, 2005). These are some of the constraints in geospatial data sharing. To address the national issues described earlier, there is a crucial need of a GIS application for spatial data correction. Online Geospatial Transaction System is, therefore, designed and developed using open source libraries. It is proposed to be implemented in PMGSY.

In the past, pilot implementation of GIS was carried out for a few states, wherein GIS enabled Road Information Management and Monitoring System (GRIMMS) was developed for PMGSY (Sajeevan et.al, 2013, 2012, 2007, 2006ab; Sajeevan 2012). However, the spatial accuracy of the GIS data was poor and the spatial shift was similar to those shown in figure 8 or worse than that. Although such spatial data may be used in isolation for limited GIS analysis; they will not be of meaningful use for geospatial data interoperability and related spatial analysis.

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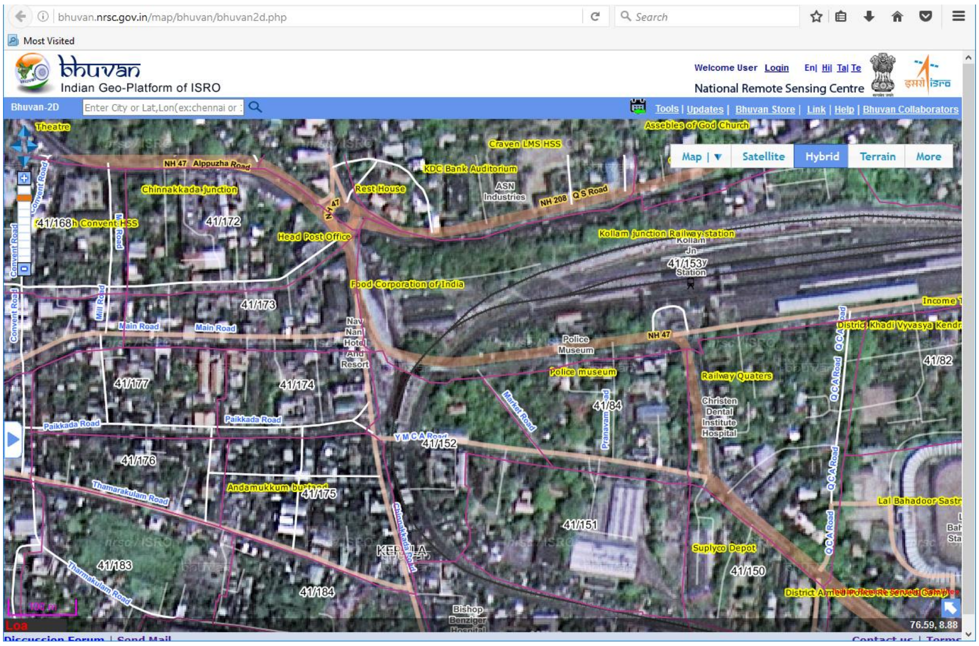

Figure 1: Spatial shift of vector layers on Bhuvan (accessed and screen captured on 22.02.2017)

2. About PMGSY National GIS

Currently, the project titled 'National implementation of Web based Geographic Information System for *Pradhan Mantri Gram Sadak Yojana'* is being executed for National Rural Infrastructure Development Agency (NRIDA), Ministry of Rural Development, Government of India in collaboration with Centre for Development of Advanced Computing (C-DAC) and all the states. The project is commonly referred as PMGSY National GIS.
Conforming to the PMGSY National GIS guidelines (PMGSY, 2016), all the states created digital geospatial data. The geospatial data creation process deviated from the traditional way of digitization to ensure position accuracy of features. The base data and the enforcing boundaries were discarded. Along with that, un-projected latitude-longitude coordinate reading on WGS84 datum was enforced. Spatial accuracy of any location on a map highly depends on how the appropriate projection parameters are used (Sajeevan, 2005). If the datum is changed, any selected location can have different geodetic coordinates (Sajeevan, 2008). Geospatial features could also be directly captured using GPS receivers rather than losing spatial accuracy through map projection conversions. By following the GIS guideline, the traditional map mosaicing task was also avoided. It was a herculean task to create national level geospatial data and correct with respect to satellite data services of Bhuvan. This enables users to access the precise feature locations on field with reference to GPS receivers either on mobile or other ways. The States departments dealing with PMGSY now have the reliable spatial data that can be used for further planning and development.

The GIS application developed under PMGSY National GIS is named Geospatial Rural Road Information System (GRRIS, http://pmgsy-grris.nic.in). GRRIS handles only the spatial data component. All other information about the features are accessed live from Online Management, Monitoring and Accounting System (OMMAS, http://omms.nic.in) and then reports/maps are generated dynamically. OMMAS and GIS data updating and management were carried out independently, which ensured the success and sustainability of the GIS application. The Web GIS application enables effective planning, management and monitoring of PMGSY using geospatial technologies by the concerned officials. As the application is open to public, online dissemination of geospatial information to general public ensure transparency of processes and increased accountability. The Web GIS application was developed over a commercial GIS engine that lacked spatial data editing function. This constraint also led to the development of online geospatial data editing application.

3. Objective

Geospatial data has the location information of the feature geometry represented in geographic coordinates. The geospatial features are represented in map as point, line and polygon. The geospatial data types, structures and transactions are complex. Spatial features can be retrieved across the Web using Open Geospatial Consortium (OGC) compliant Web Feature Service (WFS) and the features can be created, deleted or updated using transactional Web Feature Service (WFS-T) (OGC, 2017). With the following objectives, online geospatial data editing application was developed using open source software libraries.

- Using a web browser, user should be able access, add, delete or update spatial features
- A generic architecture
- Design and development of a scalable web-based GIS application
- Deployment of the application
- Geospatial data service

The objective includes designing and developing a generic web based geospatial data editing application that can satisfy the specific GIS requirements of PMGSY.

4. Methodology

The methodology used for developing the Online Geospatial Transaction System is explained subsequently. The application is developed under Microsoft .NET environment utilising the following open source software:

- Database server and spatial extension
- GIS server
- GIS SDK

4.1 Geospatial DBMS

Geospatial data may be saved in intrinsic GIS data formats or in database servers with spatial extension. Examples of open source database servers are PostGIS (spatial extensions for PostgreSQL), MySQL Spatial (spatial extensions for MySQL), SpatialLite (spatial extensions for SQLite database). Examples of commercial database servers are Oracle Spatial (spatial extensions for Oracle database) and SQL Server Spatial (spatial extensions for Microsoft SQL Server).

PMGSY National GIS required spatial in shape file format (.shp). The spatial data of Odisha state is used for the initial analysis and testing of the online geospatial data editing application. The GIS layers are also kept in PostGIS. PostGIS provides spatial objects for the PostgreSQL database, allowing storage and query of information about location and mapping (PostGIS, 2017). The aim of storing the layers in both the formats is for analyzing the response time for geospatial data retrieval and transaction from those formats.

4.2 GIS Server

There exist a number of GIS servers, which provide maps on request. GIS servers have the capability to read data from GIS data files, as well as from database servers. While the GIS servers may generate and provide user requested map in standard image formats, the geospatial features are transferred using GML that is an extension of XML. Examples of open source GIS server are GeoServer and MapServer; and commercial servers ArcGIS Server and ERDAS Apollo. Designed for interoperability, GeoServer publishes data from any major spatial data source using open standards (GeoServer, 2017). Powerful and having rich functions, we have used Geoserver as GIS server.

4.3 Open Source GIS Library / SDK

Apart from generic development environment, additional libraries/SDK are required to perform GIS functions. The client site libraries are generally JavaScript, but, the Server-side libraries are of many types. The well-known commercial GIS servers like ArcGIS Server and MapXtreme have .Net and Java SDKs. OpenLayers, Leaflet and Cesium are examples of open source libraries. We have used the well-known OpenLayers library, which is having rich support for GIS functions. OpenLayers helps to integrate dynamic map in any web page and can display map tiles, vector data and markers loaded from any source. OpenLayers has been developed to further the use of geographic information of all kinds (OpenLayers, 2017). Web clients require OpenLayers JavaScript library, which can send OGC complaint request to the map server.

4.4 Attribute Database

The attribute information about each feature in geospatial database could be accessed from diverse sources. It is advisable to maintain the spatial data separately and then link the spatial data to various databases online as per the requirements of the software application (Sajeevan, 2012). For PMGSY, all that attribute information is available in Microsoft SQL Server database of OMMAS. The OMMAS database is updated continuously by all the states. These data need to be accessed live and then make appropriate joins to the geospatial data. To achieve this, Foreign Data Wrappers in PostgreSQL can be used.

4.5 Multilingual Support

In the Indian context, the multilingual support of user interface is an important utility. GIS applications report many issues while supporting Indian languages. The language of names on the map may be set through GeoServer, however, the existing Indian language data may need to be converted to a uniform encoding. The multilingual display is configured at GeoServer level so that any software that is able to read OGC complaint services can make use of the multilingual map. Regarding OMMAS, names of the states, districts and blocks are currently available in Hindi language. Figure 2 shows the block map along with Hindi names as Web service.

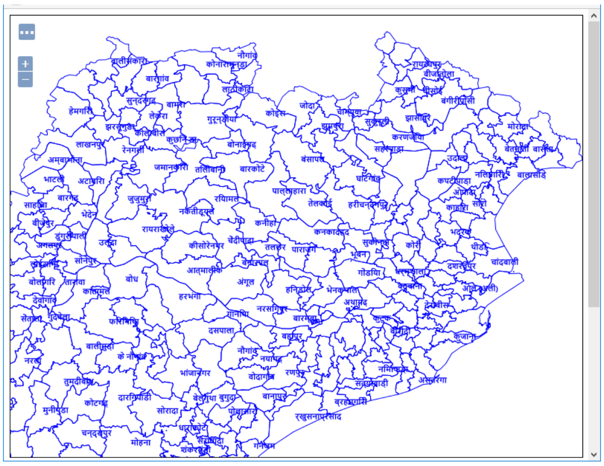

Figure 2: Block map service with name in Hindi

4.6 System Architecture

The architecture of the application is shown in figure 3. The clients should support JavaScript and need to download the required utility from the server. The External Map Servers can be Bhuvan or Google that can provide map services as WFS, WMS, etc. The client can also access these services directly from the external servers or can access through the local GIS server / Web Server. Internet Information Services (IIS) is used as Web server.

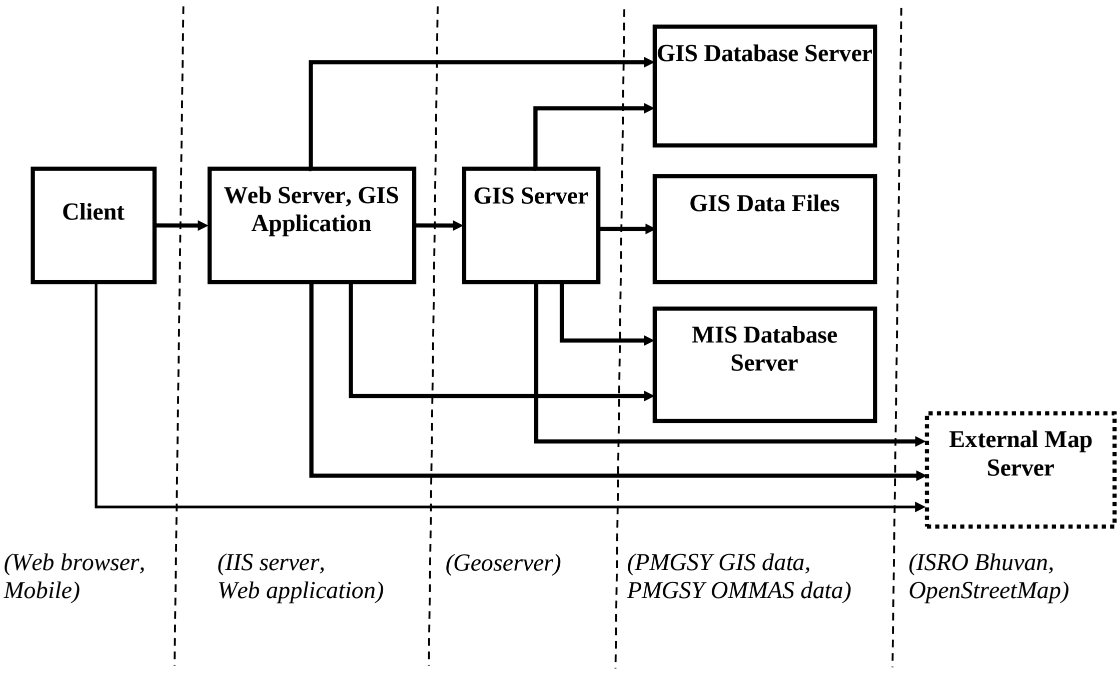

Figure 3: The system architecture

5. The Web GIS Application

With flexible architecture, design and development, a pilot of online geospatial editing application made for PMGSY. It is developed in Microsoft .NET environment. Experiments have been conducted on Apache JMeter to study the map access time by GeoServer from PostGIS and shape file data. The architecture and design of the application on open source software could become the backbone for national geospatial data programs.
On successful login (role based) user would be directed to the page along with authorized functional features and spatial extent (Figure. 4).

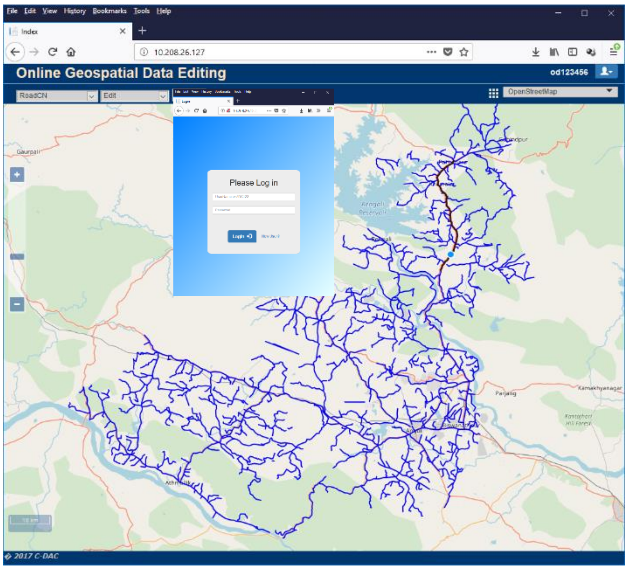

Figure 4: Edit layers on successful login

The user has the options of selecting a layer to edit, and if required, selecting a base map. User can add, edit and delete features of the selected vector layer. The user login helps assigning/restricting user activity to a selected region; for example, user updating can be limited to a block or a district. The user can select any base map that can be from map services of internal GIS layers or from external sources like Bhuvan, OpenStreetMap and Google map. Figure 5 shows base map as WMS from Bhuvan. The WMS map is rendering of satellite data and the resolution depends on the zoom level.

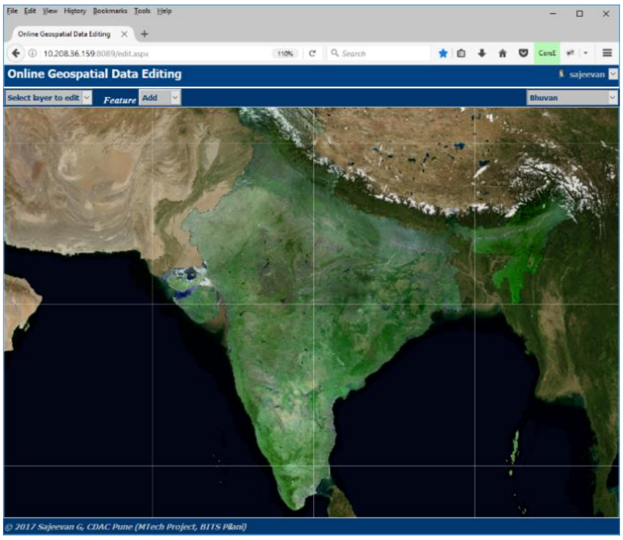

Figure 5: WMS from ISRO's Bhuvan

On selecting a layer to edit, the geometry of the features to be added would change automatically as per the layer geometry. For example, if block layer is selected for editing, feature geometry will be changed to polygon automatically. These capabilities ensure reducing the cognitive load on users and increasing the usability of the application. Figure 6 shows adding a new feature in block layer (for demonstration). The modifications made on the layer can be saved automatically or manually on the server.

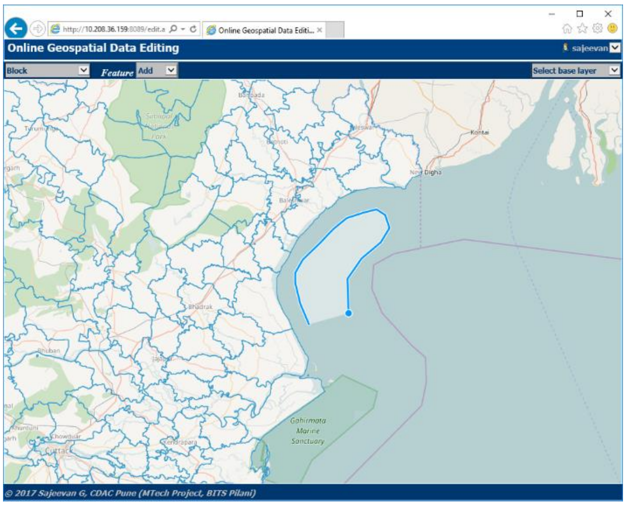

Figure 6: Adding a new feature in block layer

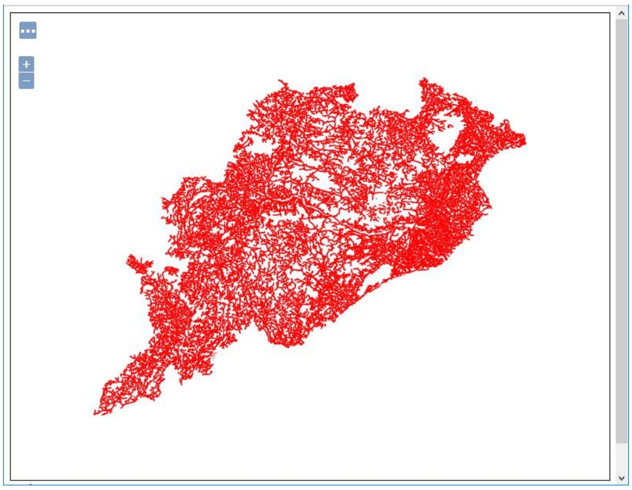

Figure 7: Road data service from shape file

6. Geospatial Data Service

The OGC standards web services started as part of the project, like WMS and WFS, can be used by any other application with or without authentication. The map services could also be accessed from any web browser as shown in figure 7.

Figure 8 shows WFS layer (BITS-OR:road_drrp_i) and WMS layer (OR layers) accessed by an open source desktop GIS software (QGIS). It shows spatial shift of old GIS layers (used in GRIMMS) on Bhuvan satellite data service. Those vector layers are corrected under PMGSY National GIS.

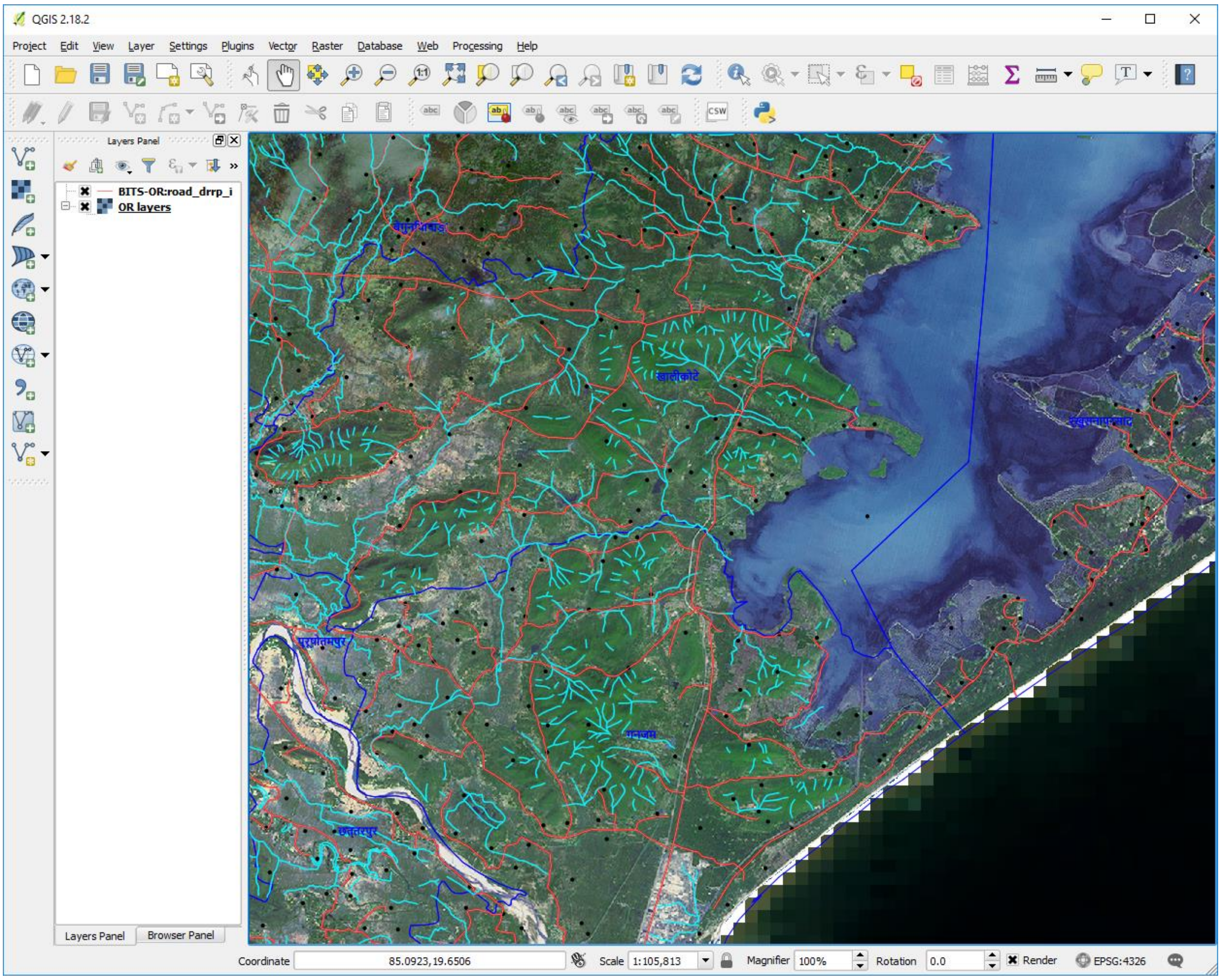

Figure 8: Geospatial data service

7. Conclusion

The massive volume of geospatial data of the country captured in digital form essentially requires spatial correction. The online geospatial transaction application would help immensely in achieving the spatial accuracy that is essential for planning, development and decision making. The application is developed using Free and Open Source Software (FOSS), thereby its benefits and aligning to the Government of India policy towards adaption of FOSS. The architecture, design and application may be used for national level GIS implementations for PMGSY geospatial data creation, planning, analysis, management and monitoring requirements. The application may also be extended to other GIS implementations. Moving the application to cloud environment can be beneficial for scalability, reliability, management, etc. Mobile applications can be plugged into the system for adding spatial data, data improvement, etc. The map services may be made available to other national geospatial projects. Considering the realistic digital spatial data requirements, crowd-sourcing can help incorporating various geospatial layers on fast pace.

The government agencies involved in planning and development should have access to accurate geospatial digital base data. It should be a collective responsibility of the government and the domain experts to bring about a change; a change for making accurate digital spatial data easily available for nation building. Rather than focusing on the elementary data conversion domain, the GIS industry should diversify on location-based services, GIS data processing, complex geospatial data capture/updating, etc. This can propel requirements for advanced spatial data and software (Sajeevan, 2017).

Various GIS technological advancements have been applied to the PMGSY National GIS so that the output could contribute immensely for the national GIS. The holistic approach initiated together with the central and state governments and private agencies delivered successful outputs. In future, the officials could focus on analysis, planning, modeling, etc, rather than hunting for reliable digital spatial data. The proposed online geospatial transaction system having geospatial data service could change the way GIS projects are handled and the GIS initiative is expected to open an ocean of opportunities for the government as well as the GIS industry. This will help decision-makers to arrive at reliable judgments easily.

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