

Web-GIS based application for utility management system

Rajeshkumar J. Ajwalia¹, Shashikant Patel² and Shashikant A. Sharma²

¹Construction and Maintenance Group

²VEDAS Research Group, EPSA

Space Applications Centre-ISRO, Ahmedabad-380015.

Email: rjajwalia@sac.isro.gov.in

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Abstract: Utility management processes are very complex, multidimensional and they require modification of traditional approaches. Managers and planners experience difficulty in data management and spatial data integration with traditional Management Information System (MIS). This paper presents a conceptual design model of a Geographic Information System (GIS) for a Web-based utility management system using open source technologies. As a case study, Web-GIS based Utility Management System (WGUMS) for six campuses of Space Applications Centre (SAC) viz., main campus, Bopal campus (technical and residential) and four residential housing colonies of center is presented. The developed web-GIS application contains physical information like campus boundary, buildings, roads, water supply lines, drainage lines, firefighting lines, pump house, wells, bore points, recharge wells, power substations, electrical light poles, solar light poles, nursery area and trees. The WGUMS is used to visualize and maintain utility assets in terms of database and operations, thus it has the potential to manage the scattered data into a single platform. Developed WGUMS is helpful in effective management of utility assets at SAC campus as well as residential area. WGUMS provides interactive Graphical User Interface (GUI) along with basic GIS functionalities over the web for users.

Keywords: GIS, Web-GIS, Open source, OGC, WMS, Utility management.

1. Introduction

Electricity distribution and water supply is the process of transporting electrical energy and water from the transmission point to the end user's points. Electricity and water are essential parts of everyday life that are often taken for granted. Like electricity and water, civilized society needs organized and well maintained other assets such as sewage lines, gardens and utility network. Using the GIS technology, complexities of utility network can be simplified and maintenance cost can be reduced to some extent. Geographic Information System (GIS) and web GIS technology can help resource managers in providing improved services. Traditional approaches are very complex to manage utility information, which are discussed later in 'characteristics of existing system' section, that upswings the need for the development of a Web-GIS based Utility Management System (WGUMS) system.

Today, the system of storing and sharing information is possible through the internet and World Wide Web (WWW). The internet technologies provide the facility to establish communication network between computers world-wide. Web services are modular, self-describing applications that can seamlessly interoperate directly across the internet. The development and availability of powerful GIS and visualization tools in conjunction with the internet have played an important role in the emergence of web-enabled management system. During the past decade, GIS has been widely used in various types of business, government and university projects. In order to utilize the available spatial datasets efficiently and effectively, web GIS has to play a significant role by providing information in decision making processes and it is not just in disseminating the

spatial data (Yang et al., 2005). Web GIS is gaining popularity and it is an important tool to share and interoperate the heterogeneous spatial data. The web based applications consent a new forms of communication as well as information sharing. In essence, Web Services are able to package data without considering the specific application environment at the client end. Different systems can achieve seamless communication, data sharing and interoperation across platforms and languages based on Web Services framework.

Since the advancement of internet and geospatial technologies, various efforts have been made to generate information and utilization of these techniques for the well-being of society. Today in the advancement of Web technology, various management systems have been developed for utility mapping, power distribution, Earth data and Planetary data dissemination and archival. Web GIS is also important in decision making process such as urban planning process (Mansourian et al., 2011), Public Transport Management System, Emergency Response System (ERS), livestock information management system (Otieno and Nigigi, 2014; Baucic and Medak, 2015; Ranade and Mishra, 2015) which have been developed using various tools and technologies. The above mentioned applications highlight a variety of specific GIS applications within different management system.

Web Map Service (WMS) interface standard provides a simple HTTP interface for requesting geo-registered maps or images from geospatial database configured with PostgreSQL and PostGIS. Open Source technologies which follow the Open Geospatial Consortium (OGC) specifications are used in

application development e.g. Geo-Server, Open Layers, Tile Cache is an implementation of a WMS-C compliant server and can easily cache the data of WMS. It makes the response speed of WMS 10-100 times faster (Green and Bossomaier, 2002).

2. Objective

The paper aimed to design and develop a management system where information can be analyzed and managers can take the decisions on the basis of available information. Therefore, the key objective is to manage the information from different sources at center level using advanced methods and technologies which perform spatial analysis for enhanced administration and management. The study was intended to develop a WGUMS system at center level with interactive Graphical User Interface (GUI) along with GIS functionalities for utility management.

3. Study area

Premises of Space Applications Centre (SAC) is the study area. It has two functional office campuses (SAC-main Campus and SAC-Bopal Campus). Besides this, SAC owns four residential housing colonies and a residential area for Students/Guests constructed at Bopal village, within Ahmedabad, Gujarat India. System modules have been developed for both functional office campuses, four residential colonies along with Bopal residency.

SAC office campuses: SAC, spread over 83 acres, is one of the major centers of the Indian Space Research Organization (ISRO). SAC focuses on the design of space-borne instruments for ISRO missions and development and operationalization of applications of space technology for societal benefits. The applications cover communication, broadcasting, navigation, disaster monitoring, meteorology, oceanography, environment monitoring and natural resources survey. SAC-Bopal campus is spread over 14.7 acres land and is well equipped with pump house, LT/HT panels, light poles, fire line, nursery, bore wells, AC-plant etc.

Housing colonies: Vikramnagar housing colony is situated on Ambli - Bopal road, approximately 2 km from SAC main campus. Antrixnagar housing colony is located behind the main campus over 7.6 acres land. Vastrapur housing colony has 288 quarters. Vastrapur housing colony is located at approximately 4 km east from the main campus over 13.84 acres land and well equipped with pump house, light poles, fire line, bore wells etc. Shastrinagar housing colony has 56 quarters. Shastrinagar colony is located at approximately 8 km east from the main campus over 0.63 acres land and is equipped with pump house, light poles, borewells etc.

Bopal residency: Bopal residency is at Bopal approximately 8 km west from the main campus over 11.92 acres land and well equipped with all utilities.

3.1 Characteristics of existing system

- All utilities information pertaining to the civil utility, electrical utility, mechanical equipment and nursery, which includes specification of pump houses, Sewage Treatment Plant (STP), lifts, buildings, roads, different features like water supply, sewage line, fire line, electric line, substations, High Tension (HT) / Low Tension (LT) distribution, street lighting and service connection of each quarters etc. are maintained by analogue methods.
- The data for water supply, firefighting, and drainage, details of buildings, roads, pump houses, wells, trees, electric cables and street light poles are maintained in separate map sheets. It is very difficult to update paper maps timely in traditional methods.
- In traditional system, the database are not managed and maintained in form of information where decision makers can extract information regarding buildings for plastering, painting, road maintenance, pump houses, wells locations, trees, electric cables, street light poles, substation equipment, LT panels, feeders and fault logging etc.
- Within the organization a desktop application has been developed for utility management system (Ajwalia and Patel, 2014), where managers can manage spatial datasets using desktop application. The developed desktop application may not be available for general users to view their utility information.

The design and implementation of a WGUMS for SAC, Ahmedabad is to enable efficient network management by providing instant information access to all concerned engineers. This is essential to minimize time for locating any lines, buildings, power restoration and efficient planning for preventive maintenance. This paper demonstrates the use of open source GIS technologies and web services architecture for development of WGUMS. The interactive web user interface is built in using the ExtJS and the GeoExt frameworks with the OpenLayers libraries which are used as a main map client. Finally, a dynamic Styled Layer Descriptor (SLD), generated with a User-Friendly Desktop Internet GIS (uDig) open source software script is incorporated for creating interactive and user oriented maps.

Development of WGUMS is combination of various types of assets management which are essential in an organization as well as residential colony. The system contains electricity, drinking water supply, waste water line, sewage line, gardens, Diesel Generating (DG) set, Low Tension (LT) Panel and Sewage Treatment Plant (STP), along with office and residential buildings and many more. The beauty of the developed application is its ability to handle all assets on a single platform.

4. Tools and technology

The web based system is developed using various open source software and libraries, which are directly involved in web application, while many other desktop

GIS applications were used in preprocessing of spatial database and advanced analysis. uDig software is used for SLD (Styled Layer Descriptor) generation and editing. It is an open source (EPL and BSD) desktop application framework (<http://udig.refrlections.net/>). PostgreSQL is a database server for storage and transaction management. In the developed application, the open source database PostgreSQL with PostGIS extension could support spatial features very well. PostgreSQL is a powerful, open source object-relational database system. PostgreSQL tool can be downloaded from the web portal <http://www.postgresql.org>. PostGIS is a middleware between PostgreSQL and GIS engine. PostGIS libraries downloaded from the web "<http://www.postgis.net/>". GeoServer is an open source software server written in Java that allows users to share and edit geospatial data and is used for interoperability and publishing OGC web services. GeoServer forms a core component of the Geospatial Web (<http://geoserver.org>). Open Layers is an open source, client side JavaScript library for making interactive web maps, viewable in nearly any web browser. OpenLayers makes it easy to put a dynamic map in any web page. The open Layers libraries are archived from <http://www.openlayers.org/> web portal. GeoExt is used for rich web mapping. GeoExt is built on top of the robust OpenLayers JavaScript mapping library and the rich graphical components of ExtJS. The core structure

and the interface of the geoportal have been developed with the ExtJS framework. ExtJS is a cross-browser JavaScript library for building rich Internet applications. The Web user interface is built using the ExtJS and the GeoExt frameworks with the Open Layers as a main map client. GeoExt libraries archived from <http://www.geoext.org> web portal. The ExtJS is a popular JavaScript library used for building Web applications and ExtJS libraries are downloaded from <http://www.snecha.com>. A SLD is an XML-based mark-up language that allows user-defined symbolization of map layers. The SLD schema can be used for styling both vector and raster data, and the SLDs are used for map rendering by Web Map Services.

5. Framework

Figure 1 shows the framework of developed WGUMS application. It adopted three tier architecture i.e. application layer, service layer and data layer. The web server transmits the request and response at the client side; the web server deals with and distributes the request whereas database server provides data retrieval, storage, modification etc. Application server contains various models such as layer rendering, GIS functions etc.

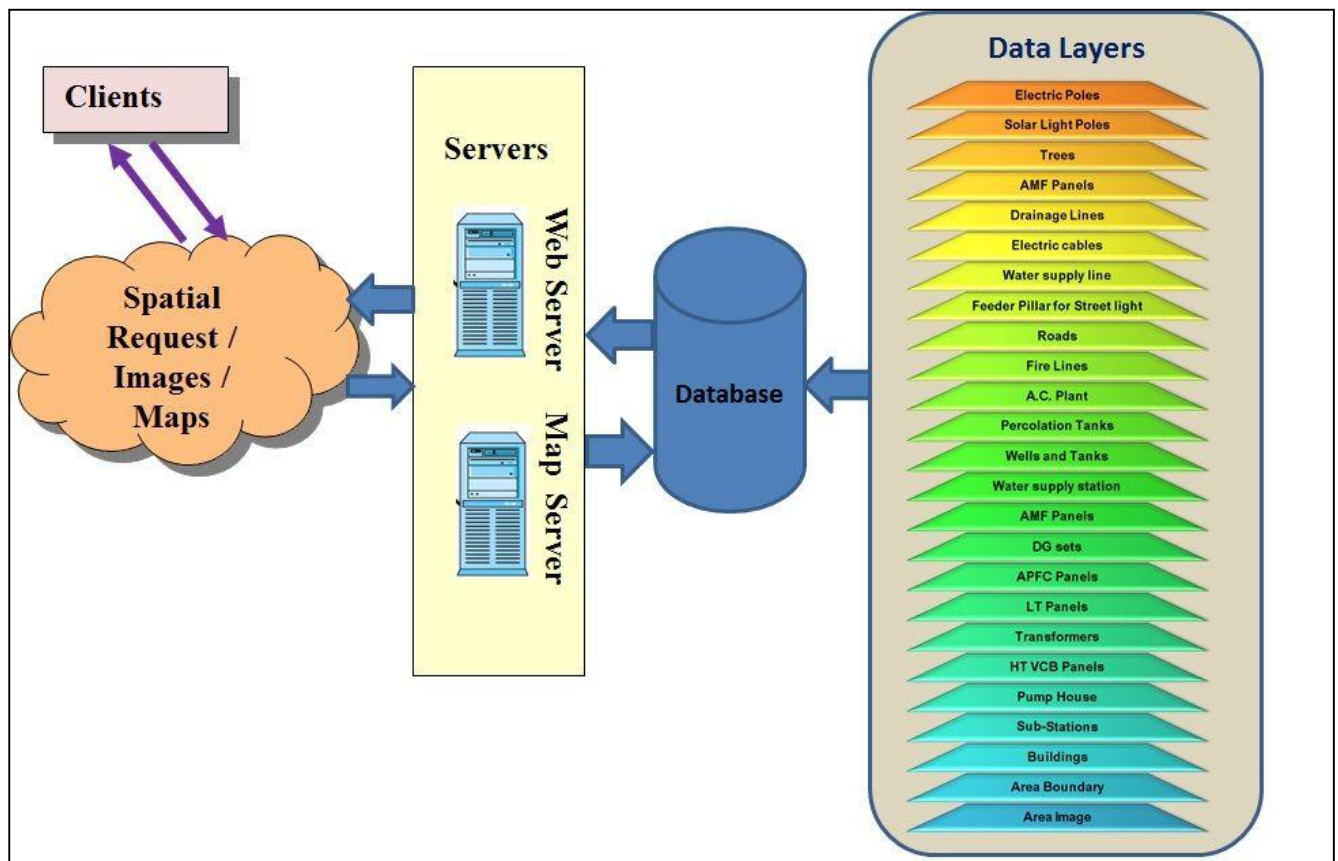


Figure 1: Basic framework

List of spatial layers integrated in WGUMS is described in Table 1 along with geometry of the layers and associated attributes. Table 2 describes the menus and

sub-menus categorized in WGUMS and their associated information. The entire study area is categorized in three major parts namely office campus, housing colonies and

residential areas. Under each category information is classified in spatial (map and layers) and non-spatial (tables and photographs) datasets.

Table 1: Spatial layers and geometry type

Sr. No.	Layer Name	Data type / Geometry Type	Attributes
1	Electric Poles	Vector (Point)	ID, Name, Cable Size, Fitting, Type of Pole
2	Solar Light Poles	Vector (point)	ID., Layer, P-Max, Wattage-FF, IPM, ISC, VOC, EFF_M, EFF_C etc.
3	Trees	Vector (Point)	ID, Name
4	AMF Panels	Vector (Polygon)	ID, Name, ACB-Make, Make of R, Model Type
5	Drainage Lines	Vector (polyline)	ID, Diameter, Material etc.
6	Electric cables	Vector (polyline)	ID, Cable Size, Source, Destination, Sub-Station etc.
7	Water Supply Line	Vector (polyline)	ID, Diameter, Material etc.
8	Feeder Pillar for Street Lights	Vector(polygon)	ID, Wattage, Pole Type, Location, FPS-No, Fitting Type, Cable, etc.
9	Roads	Vector (polyline)	ID, Road type, Size, Source, Destination, Length, etc.
10	Fire Lines	Vector(polyline)	ID, Type, RPM, Pump-No., Model No., Make, Location, Installed etc.
11	A.C. Plant	Vector(polygon)	ID, Building-No, Layer, Name etc.
12	Percolation Tank	Vector(polygon)	ID, Depth, Name, Size etc.
13	Wells and tanks	Vector(polygon)	ID, Depth, Name, Size etc.
14	Water supply station	Vector(polygon)	ID, Name, Size, Type etc.
15	AMF panels	Vector(polygon)	ID, Name, Model Type, Make of R, ACB Make etc.
16	DG set	Vector(polygon)	ID, Name, Year of Make, Volts, Style, Sr. No., Speed, Phase, Make, Frequency etc.
17	APFC Panels	Vector(polygon)	ID, Name, Capacity, Relay Make, Relay Mode, Stages etc.
18	L T Panels	Vector(polygon)	ID, Cable Size, Capacity, Feeder No, Frame, Frequency, Name, etc.
19	Transformers	Vector(polygon)	ID, Name, Capacity, Frequency, HV-Amp., HV-Volts etc.
20	HT VCB Panels	Vector(polygon)	ID, Name, Type, Weight, Rated volt, current, Frequency etc.
21	Pump House	Vector (polygon)	ID, Building No., Discharge, Head, HP/KW, RPM etc.
22	Sub Stations	Vector (Polygon)	ID, Name, Location, Capacity, Make
23	Building	Vector (Polygon)	ID, Building No., Name etc.
24	Area Boundary	Vector (Polygon)	ID, Area, Perimeter etc.
25	Area Image	Raster (Geotiff)	RGB image for Visualization.

Table 2: WGUMS menu and description

Main Menu	Sub Menu-1	Sub Menu-2	Sub Menus-3	Details
Centres	Campus	SAC Main Campus	View Map	Layers Visualizations with Basic GIS functions for SAC Main Campus.
			Substation details	Sub-stations details in tabular form for visualization.
			AC-Plant Details	AC-Plant details in tabular form.
			Building Details	Information about buildings in tabular form.
		Bopal Campus	View Map	Layers visualization with information in map window along with GIS functions.
			Single Line Diagrams	Visualization of Single Line Diagrams (constructed and proposed buildings).
	Housing Colonies	Vikramnagar	View Map	All layers overlay and visualization of Vikramnagar colony in map window along with GIS functions.
			LT Panels	Complete LT-Panels list with all information in tabular form, installed in Vikramnagar colony.
			STP	Sewage Treatment Plant details in table form.
			Pump House	All information in Tabular form and picture form can be visualize for vikramnagar colony.
			Fire Fighting Lines	
			Building Details	
			Maintenance	
			Single Line Diagrams	
			Service connection	
		Antrixnagar	View Map	Layers visualization with information in map window along with GIS functions for Antrixnagar colony.
			Pump Details	Pump houses details available in a table form.
		Vastrapur	View Map	Layers visualization with information in map window along with GIS functions for Vastrapur colony.
			Single Line Diagram	Single Line Diagrams of Electric supply in Vastrapur colony.
			Photographs	Recent Photographs of Buildings, Gate, office, School etc.
		Shastrinagar	View Map	Layers Visualizations with Basic GIS functions for shastrinagar colony.
			Service Connections	Service connections details available in tabular form.
	Residential Area	Bopal Residential	View Map	All layers overlay of Bopal residential in map window for visualization along with GIS functions.

6. Application

6.1. The web application framework

Figure 2 illustrates architecture of the developed application, where user can send data request from a web browser as HTML/JavaScript and they can get

response from server in HTML/ JavaScript client node. Web server Apache is handling the request from client and the same is passed to Geo-server which is used as map server; from map server, request has been responded to the client in form of spatial data or query results in tabular form.

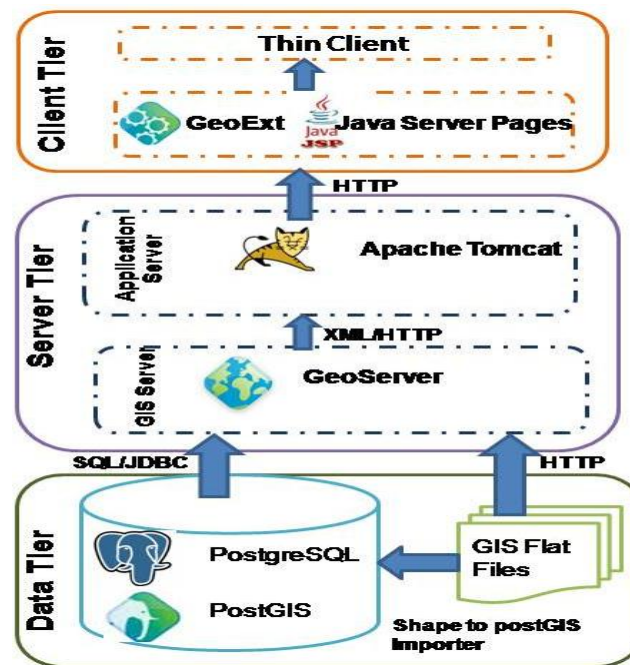


Figure 2: Service architecture and data sharing

6.2. Implementation

Based on the architecture of developed web application, the spatial data management and visualization system was completed in this section. First, the original data were standardized into datasets by unifying the coordinate system and file format using desktop GIS software. The data were collected from different

sources, for example, maintenance data in the form of Microsoft Excel (MS-Excel) file; linear features and polygon features from CAD (Computer Aided Design) files; electric poles and feeder's locations collected from Mobile Global Positioning System (GPS) device. Figure 3 describes flow chart depicting preprocessing of the database for application.

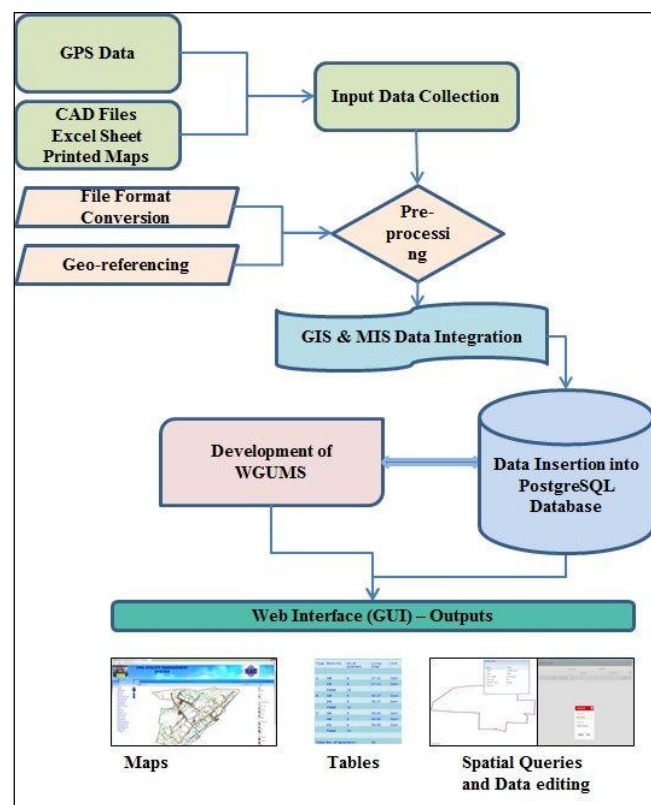


Figure 3: Pre-processing and implementation flow chart

The database preparation and metadata standardization of spatial data has been carried out in following steps:

- GPS Point Collection: First step is to collect GPS locations survey of bore point, poles and tree; this involves the database preparation of utility assets, followed by the preparation of GIS base map.
- Digitization: Second step is the digitization of utility assets which were not included in digital maps such as lines, building, substations, feeders, wells, and poles from geo-registered paper maps. Vector layers were imported from CAD file and converted into shape file format, spatial referencing with base map has been performed in converted shape files. Subsequently, geo-referenced database schema has been defined for each vector layer. All required attribute information incorporated with vector layers using join operations along with spread sheets.
- Pre-processed spatial data imported into Post-GIS database.
- Eventually, a Web GIS application developed using open source GIS technology.

The spatial database description has been categorized into three levels; datasets, layers and maps. Dataset has been prepared as discussed above. A layer is referred as a dataset that completed specific style conversion and can be visualized in map window (Yin and Feng, 2009). Map is a combination of one or more layers with specific style specification where the information can be extracted using visual interpretation.

7. Use case model and diagrams

Web GIS system presented in this paper is used by two classes of users: web GIS users and web GIS portal administrators. General relationship between user classes represents ability of a user to play multiple roles. Web GIS users are the most general class with the

visualization and rendering functionality available along with basic GIS functions. Web GIS users can access the system through a web GIS portal for viewing maps and querying geographic features. Authorized web GIS portal administrators have access to all functions of their developed GIS applications. Finally, the portal administrator is responsible for defining content that will be available to web users. An important feature of developed web GIS portal is the ability of an integration of spatial information with MIS dataset. The characteristic of WGUMS is defined in two levels of information integration. First is display level integration that consist map composition formed by overlays of various layers and their SLD definition. Second level is database update and basic GIS functionality integration.

Use case diagram is used to describe the relationships among the functionalities and their controllers. These diagrams represent the use case view of a system. A use case represents a particular functionality of a system. These controllers are known as actors. Figure 4 describes the role of administrator, where administrator can extract information from various sources viz., CAD files, field data, and spread sheets and administrator can manage to insert and update the database. Figure 4 illustrates the use case diagram, where administrator plays an actor for spatial and non-spatial data management and backup restore activities for the system.

Figure 5 describes the use case diagram for map visualization and overlay of layers. User can view maps of utilities along with associated attribute information using 'http' web link (e.g. Vikramnagar residential colony, SAC campus, Bopal Campus, Shastrinagar colony, Antrixnagar colony, Bopal residential area, Vastrapur residential colony). User can visit map page via click on "View Map" link on home page and also can mark desired layers as visible over map area.

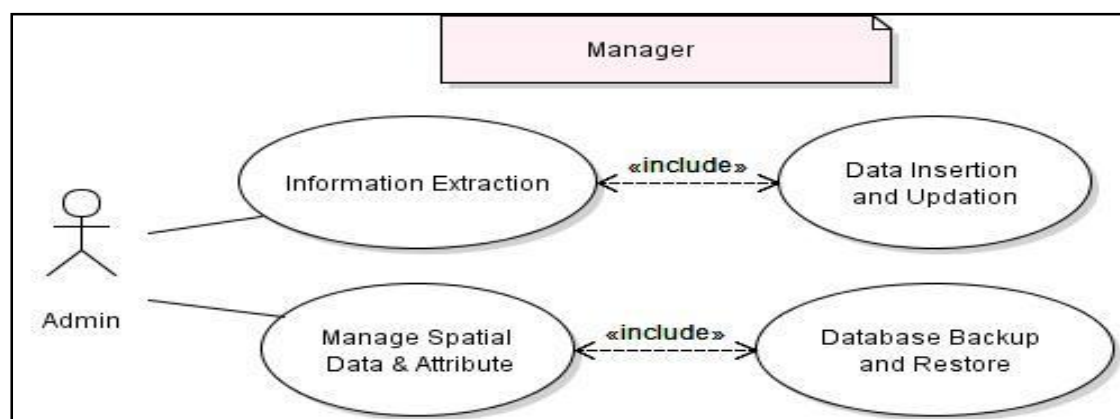


Figure 4: Use case-1 for data insertion and management

Basic GIS functionalities are provided in the System to render layers within the map area. Figure 6 illustrates the

Use case-3 diagram where, user can zoom-in, zoom-out, pan layer on map area. Full extent is the functionality to render all active layers with common bonding box over map area. Measurement functionality has been incorporated for features over map area (length

measurement for line feature, area measurement for polygon feature etc.). Zoom to particular feature

function provides the functionality to search that feature over map and render map to specific feature.

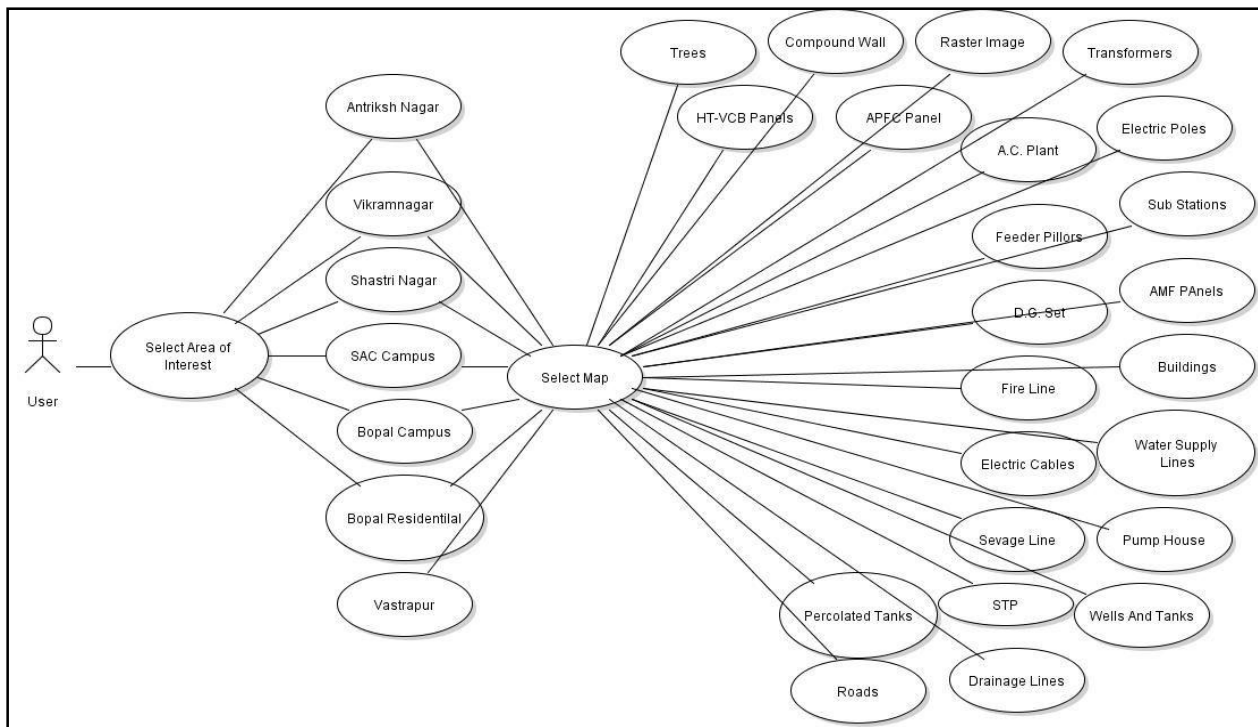


Figure 5: Use case-2 for map visualization

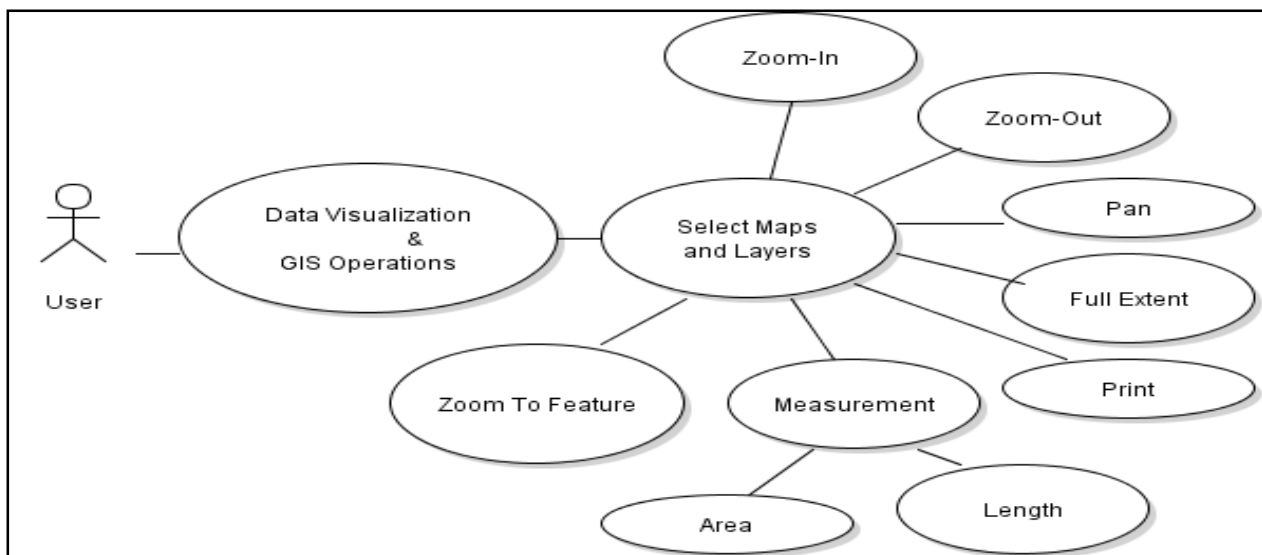


Figure 6: Use case-3 for map visualization and GIS operations

Performance of the map pages in WGUMS is governed by on hardware configuration and network connectivity, with present configuration home page response is 1.36 seconds minimum response time, 3.21 seconds maximum time and 2.96 seconds is average time.

The developed WGUMS application may provide a wide range of data for various types of analysis to enable routine maintenance and management. Strength of GIS is integrating data and preparing it for analysis or modeling apart from tying together data from various sources which makes it an important tool for planning

and decision making. WGUMS is able to display legend of all layers displayed on the map. This legend is represented by the symbol of each layer with color and the name of the layers in the legend list. System displays coordinate of the current mouse position. User can see co-ordinate only when the mouse pointer is inside the map area. If the mouse pointer moves beyond the map area the system will not display the coordinate. User can measure length of cable, roads, water supply line, firefighting lines, drainage lines from one place and other place in entire SAC-ISRO centre. User can query

any layer of the GIS map to get the attribute data for a particular feature of that layer. User has to click on any feature of a particular layer to get the attribute of that feature.

Developed system provides facility for viewing of maintenance schedule, HT distribution and substation

layout, as shown in Figure 7 to 10. Figure 11 shows maintenance schedule menu for the themes in the WGUMS and figure 12 represents maintenance schedule in tabular form under WGUMS.

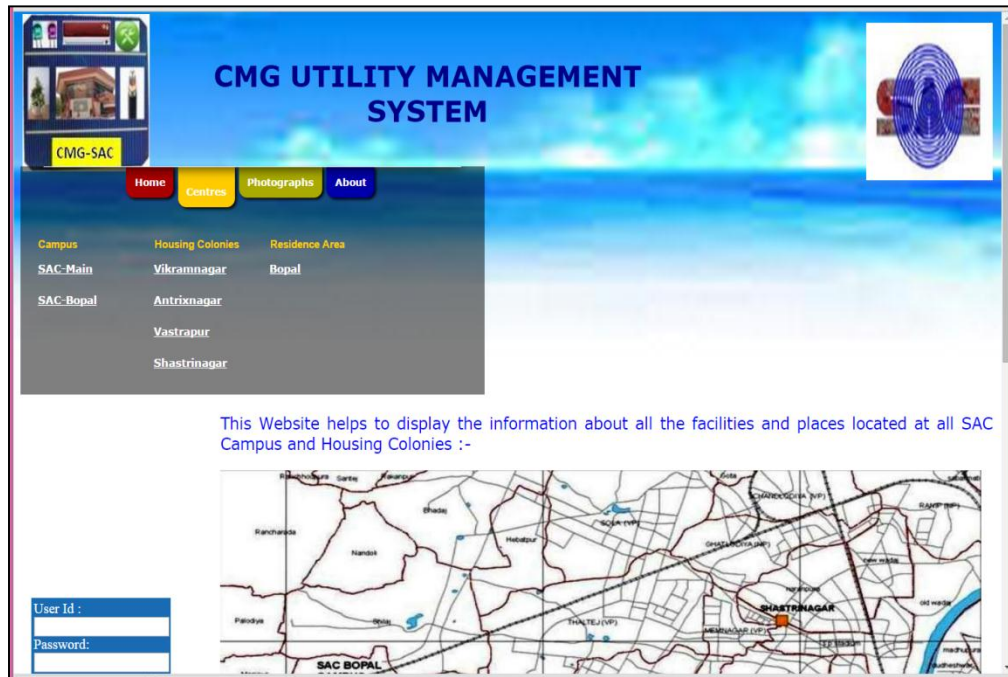


Figure 7: WGUMS home page

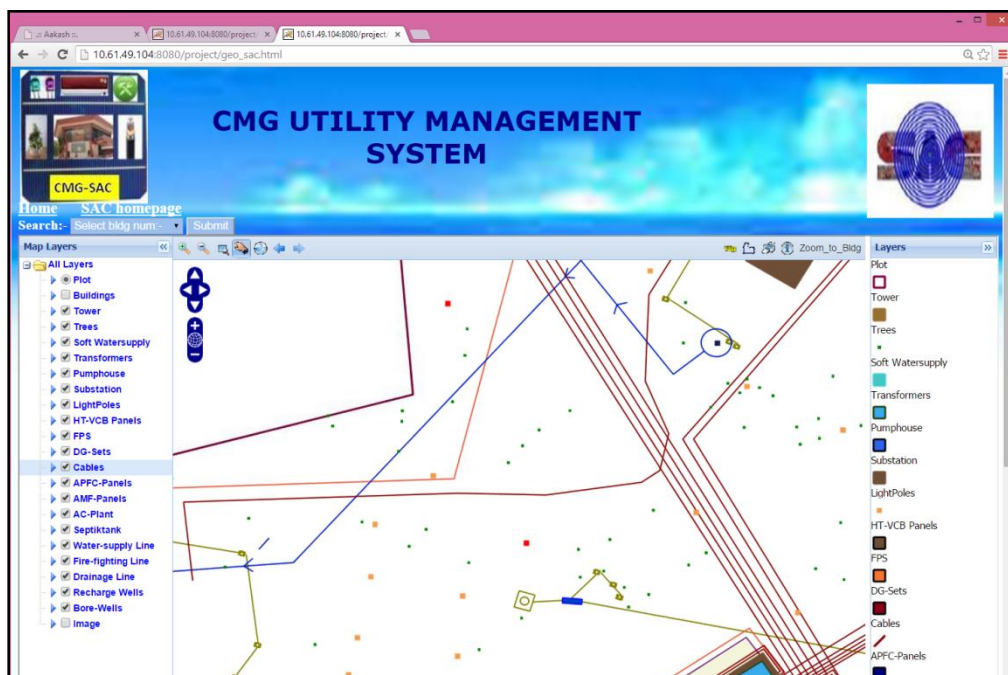


Figure 8: SAC campus-sub stations with panels and cable

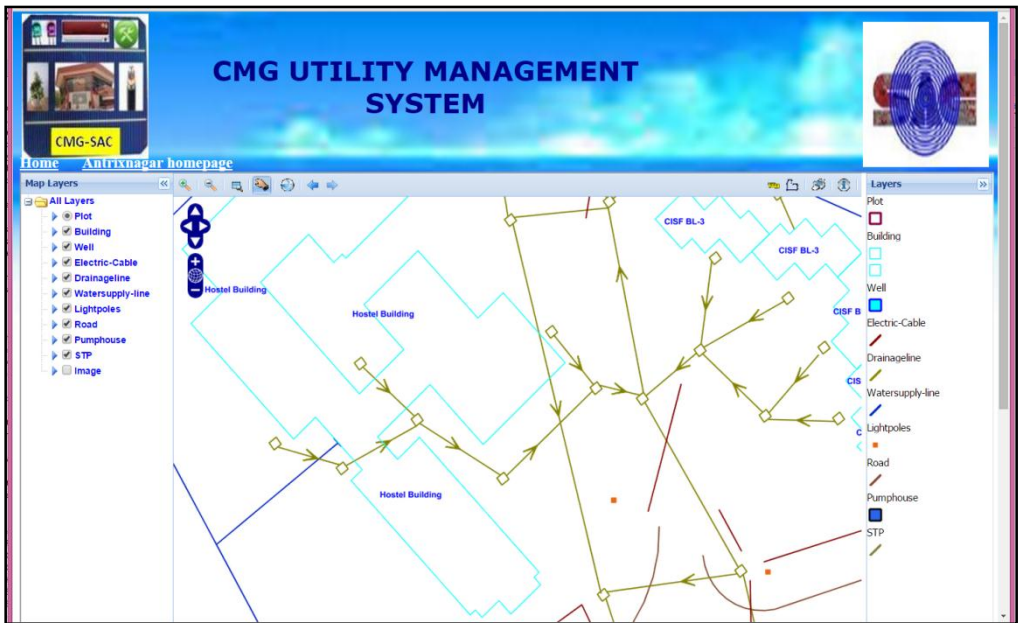


Figure 9: Antrixnagar residential colony with different utilities

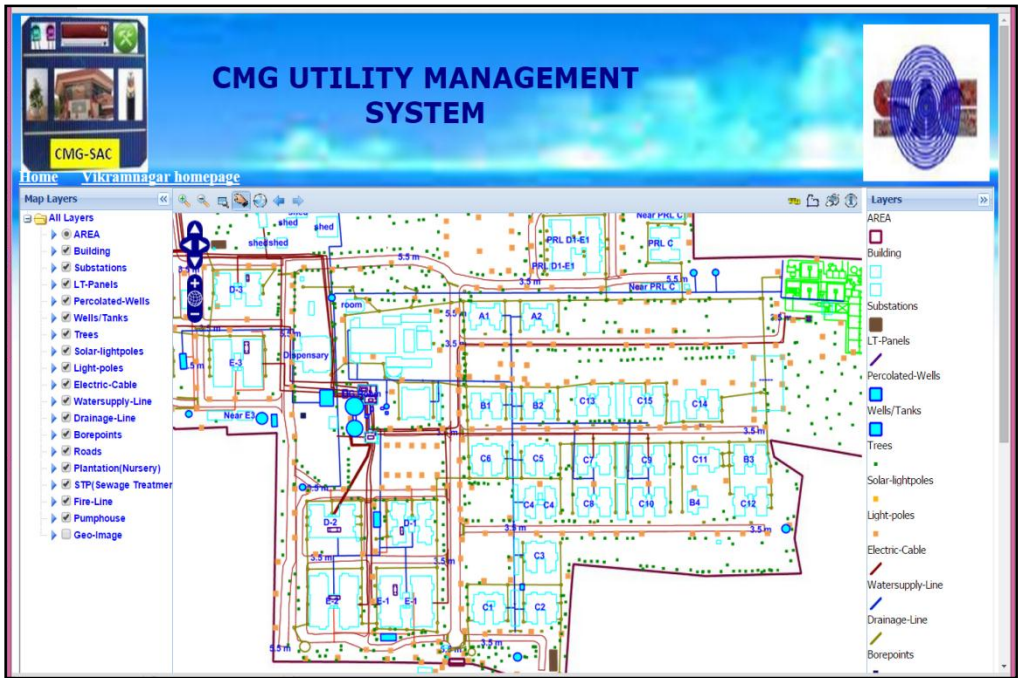


Figure 10: Vikramnagar residential colony with different utilities

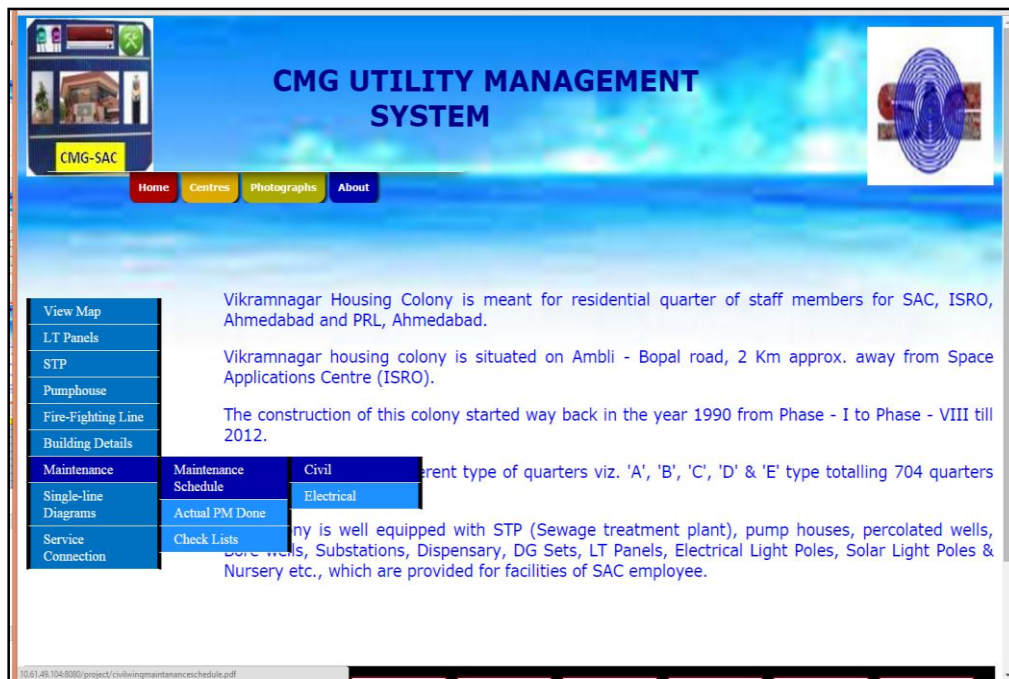


Figure 11: Maintenance schedule for Vikramnagar housing colony

CIVIL WING MAINTANANCE SCHEDULE AT VIKRAMNAGAR DOS HOUSING COLONY.		
	MAINTANANCE ITEMS	FREQUENCY OF MAINTANANCE
➡	Painting of Quartres	After every three years
➡	Plastring of Internal walls	As and when required, depends on conditions of wall
➡	Plastering of External wall	As and when required, depends on conditions of wall
➡	Painting dooors/windows	After every three years
➡	Painting [white wash]	Yearly
➡	Periodic cleaning of water tank	Half Yearly
➡	Terrace cleaning	Quarterly
➡	Sewage lines Cleaning	Yearly
➡	Grass cutting	As and when required, depends on conditions

Figure 12: Report of maintenance schedule for Vikramnagar housing colony

Conclusion

WGUMS will help in identifying pipe lines, electrical lines, sewage lines, buildings, parking areas and gardens etc. for better understanding and identification. From the present development authors can conclude that this is an attempt to develop a WGUMS for spatial planning in the field of utility management, however still there are scopes for future advancement in the system capability by adding some advanced functions and modules in account to lodge user's complaint, further,

Administrator or managers can track the registered complaint whether it is attended by concern technician and regularly updated. This paper provided a practical web GIS framework combined with latest web services technology and open source projects. Based on this solution, and spatial data services were developed to access and publish spatial data. The spatial data management and visualization system was developed to provide a new solution for the public to share geospatial data on the web. The WGUMS is developed for visualization and analysis of electrical assets, pipeline,

sewage lines, trees and gardens. The developed system contains the facility to interactive visualization spatial data and in-situ data.

This WGUMS application has been deployed in intranet, to facilitate user from SAC for map visualization from different locations and managers or planners can view and manage from anywhere within the Centre. The software is useful for planning, maintenance, and improvement of information standard and decision making processes, still there is scope for future advancement in the system capability by adding some analytical modules in account to decision making process for utility management.

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