IDENTIFICATION OF WEBGIS DEVELOPMENT POTENTIAL AND ISSUES - A LAND AND WATER CASE STUDY APPLICATION FOR MORATUWA, SRI LANKA

E.A.G.Chandramali,
Department of Civil Engineering, University of Moratuwa, Moratuwa
(Gayani.edirisinghe@gmail.com)
N.T.S.Wijesekera,
Department of Civil Engineering, University of Moratuwa, Moratuwa
(sohan@civil.mrt.ac.lk)

Abstract: Popularity of internet use is rapidly increasing. Hence, the demand is high for Web based GIS tools. The need to handle heavy maps and attribute datasets, often increase issues especially with respect to the time taken to serve maps and to filter user desired information for delivery. A WebGIS based land and water information management system was developed for a land extent of approximately 2.5km² within the Moratuwa DSD of Sri Lanka. Information of roads, buildings were collected as land data while water and stream information were collected using an extensive field survey. The developed WebGIS application integrates digital base maps and feature attribute data of the selected case study area and facilitates operations through a user-interface while offering a variety of querying and reporting options. This application which was named GeoInfo WebGIS, possesses a very high potential to serve the users through i)Map to Map ii) Map to database iii) Database to Map and iv) Database to Database functions. The application was tested and verified through a consideration of user satisfaction and accuracy. GeoInfo WebGIS was developed on MS4W framework, PostgreSQL was used as the database. Non-responsive situations, high time consumption when loading the data layers, map overlaying issues and delay in refreshing the maps are performance issues identified through the application development.

Keywords: Geographic Information System, Land and Water Information Management

1 Introduction

Importance of managing land and water has been recognized throughout the history and with the computer databases and information systems coming in to place, there had been many efforts to develop land and water information systems (Wheater& Evans, 2009, Kumar, et al., 2006, Hallett, et al., 2003). The most recent development of these systems target geographically distributed systems. So that the spatial heterogeneity associated with the land and water information systems can be better visualized and analyzed (Thapa& Murayama, 2008, Liu, et al., 2011a). The land and water management systems not only need to be specialized in the analysis and management of resources, but they also require to be capable of providing information such as their ownership, occurrence, neighborhood, use, accessibility, etc., for administrative and management purposes.

With the recent rise in mapping and map reading capabilities, there is a need to develop more down-to-earth map based information systems that could be understood and used by non-experts. In the development of web based mapping systems, the main concerns are user friendliness, the speed of access and delivery at right time (Choi, et al., 2005, Adnan, Sigleton and Longley, 2010). The present work is an attempt to carry out a case study application to evaluate the design, development and implementation issues of Map based information systems. Selected study area for the work is approximately 2.5km² surrounding the University of Moratuwa premises, in Sri Lanka.

2 Methodology

2.1 Conceptualization

Application development process is described in Figure 1. A literature survey to determine the background status of WebGIS, the conceptual design, followed by development and testing were the key elements in the adopted methodology. The present web GIS application was named as "GEOINFO WEB

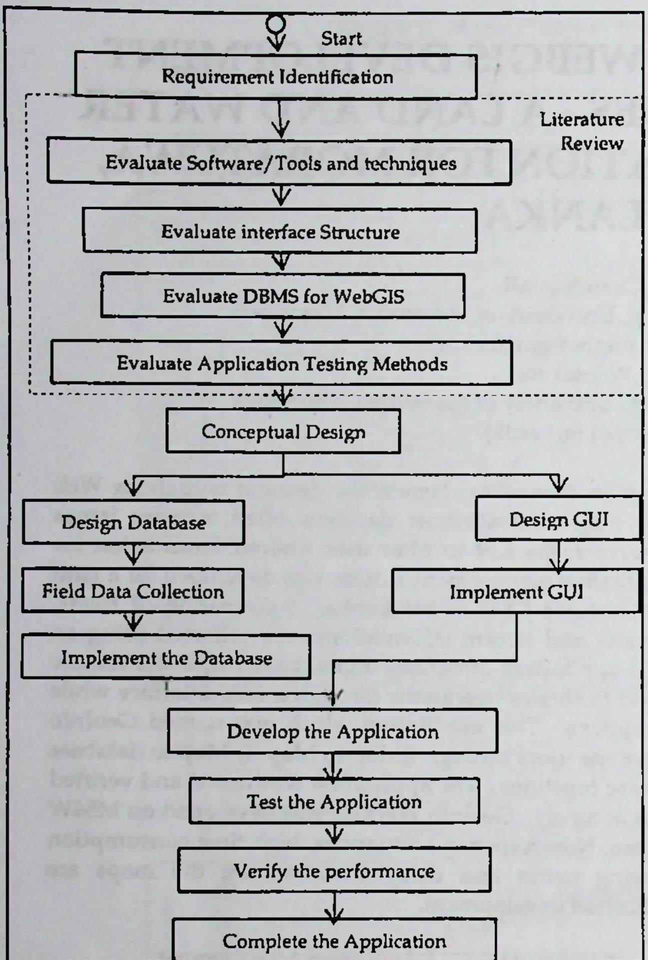


Figure 1: Application Development Process

GIS" due to its capabilities to deliver and present land and water information over the world wide web.

GeoInfo WebGIS application is designed with the facilities to search buildings and roads as land information while streams were chosen to represent water information. In this, direct feature search, attribute search and a selected extent based search were incorporated to capture Point, Line and Polygon features representing various data. Together with the basic capabilities of Zoom In/out maps, pan, full view, identify, find locations, clear selections, measure length and measure area. This application also facilitates the performing of Land feature classification, data layer handling, over lay operations, background image changing and location labeling functions.

In WebGIS applications, the combination of Data and Model Systems and User Interface form the main components that contribute to functionalities (Enge, et al., 2003). In this the Model System consists of three key functional modules as GIS Mapping, Information Query, and Multi Media (Liu, et al., 2011b) . GIS mapping model consists of the base map which supports as the background for GIS operations, the maps such as Province, District, Divisional Secretary Division and GramaNiladhari Division for administrative boundary identifications, and maps of buildings, streams and roads for specific feature capture. Information Query model enable execution of user queries on roads, buildings and streams.

The data system is to integrate geographic distribution of land and water information to achieve the module functionalities. This consists of road, building and water stream information systems. Road information system consists of the type, width, beginning and end, length of units and the capability to carry out a query based summary. Building information system consists of name, postal address or assessment number, administrative division, number of occupants of units and query system based on building type, administrative boundaries, purpose of building etc.. Water stream type, its beginning and end, administrative references, are the data that facilitate querying in the water information system. User interface design was done with an evaluation of current WebGIS applications in order to fulfil the user requirements and expectations, and the goals of the application.

2.2 Functions

Functions to be carried out by the application were recognized as i). GIS functions and operations ii). Loading and unloading of raster and vector layers and iii). Database functions and operations and iv) Featuring multimedia data operations. Functional capabilities in the design was done to fulfill the user transactions between maps and database. In the present work these functionalities were categorized as, i). Map to Map ii). Map to Database iii). Database to Map and iv). Database to Database functions where the consideration was activity commencement and destination of delivery. Under this concept, Map to map functions begin with a map and affect the results on a map component. Map to Database functions commence with a map and then results are produced in text format associated with the database queries. In the Database to Map category a database query is taken as an input to generate and display the user required information as maps. The set of functions in which queries and results both have similar text formats and originating from the database fall into the category of Database to Database.

Since the application is to function as a land and water information system, the capability to work around a building, road or a water stream was taken as the prime target. In this connection the following were included i). Query for land and water data based on attributes; ii). Display the query result on a map using GIS options (Zoom and Highlight); iii). Identify the attributes of a selected land and water feature; and iv).select land and water features with reference to a location or boundary.

3 Application Development

3.1 Data and Database Development

3.1.1 Field Data Collection

For the Case Study development, land features and attribute information were collected from the study area which is semi urban. The field data collection was completed with the use of 77 person days by considering the study area as nine zones. Data compilation, checks for collection and recording errors, digitizing and map making was carried out with additional support. Data collection supervisors were deployed along with the main author to supervise the data entering and verification.

Field data collections commenced with Google map, interpretation and digitizing to capture building polygon data. 5175 buildings, 41 roads and 2 water streams were identified though the field data collection. Land cover observation from Google map estimated the existence of 6226 buildings. Data collections were carried out using a Zoning system (Figure 2). Details of field data collection and resource requirement quantifications with respect to the field data collection is in Chandramali and Wijesekera (2012).

3.1.2 Data, Data types and formats

Google maps downloaded from an online application were georeferenced using 1:10,000 topographic maps of the Survey Department. JPEG file format was selected for the raster data.

Table 1: Categorization of Functions Embedded in the Application

Function Category	Sub function	Description	Output
Database to Database	Display Categorized information	Query land or water information based on its primary key	A feature information is displayed e.g.: Search a house by its address
	Display list of information	Select the features within range of values	A list of selected features is displayed e.g.: Search for houses within Moratuwa DSD area.
	Display specific information of a selected feature	Select a feature for known information	Display the attributes , and related features for the selected feature. e.g: Select a house and its information such as people in house, roof colour, size of the house etc..
Database to Map	Highlight Feature	Query a feature to make a prominent visualization on map by changing display to highlight with a specific colour	Highlight a selected feature on map. e.g.: Highlight the selected house on map
	Zoom	Increase or decrease the viewing scale of a map to suit a user specification	A map is zoomed to or out of a selected features. e.g. zoomed to the selected house
Map to Database	Identify	Select a feature on map to capture identified information	Display feature information on the map e.g.: click on a house and display the house information on map.
	Get measurements	Identify the limits of a feature from the map to measure length or area occupied on map	Display the area or length of a screen selected ground parcel in a selected unit of measurement
Map to Map	Zoom in/out	Select an area on map to increase or decrease the viewing scale of map window	Zoom the view to a map area selected by cursor
	Full view	Display of maps to the limits of a user desired extent	Extend the map display to a pre-defined area

Table 2: Data and Data Sources for GeoInfo WebGIS Application

Data	Type	Size No of Attribute	Attribute	Data Capturing Method
Building	Polygon	4299	Identity Number (ID), Name, Number of floors, Roof colour, Permanent/temporary nature	Field survey Digitizing of Maps
Roads	Polygon	41	Road ID, Road Name, From Location, To location, IS Main, Road Type, Length	Field survey, Digitizing Maps, Road map of Municipal Council
Streams	Polygon	3	ID, Name, Length, Type	Field survey, Digitizing Maps
Address	Polygon	5089	ID, Floor ID, Sub unit, Postal number, Street, purpose	Field survey
Person	Point	14780	person ID, Name, NIC, Age group, sex	Field Survey and Example Datasets
Province	Polygon	9	ID, Name	Map of Sri Lanka, Survey Department
District	Polygon	24	ID, Name	Map of Sri Lanka, Survey Department
Divisional Secretary Division	Polygon	332	ID, Name	Map of Sri Lanka, Survey Department
GramaNiladhari Division	Polygon	13998	ID, Name	Map of Sri Lanka, Survey Department

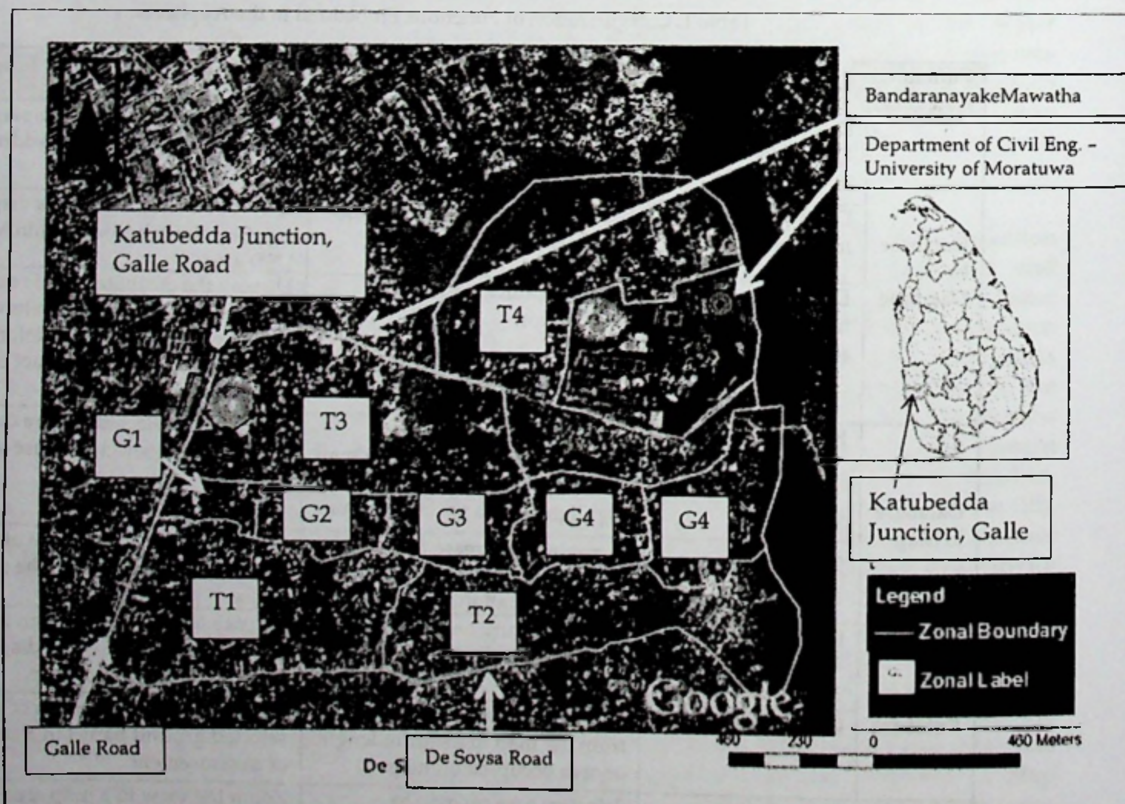


Figure 2 : Study Area for Data Collection

In the present work a maximum scale of 1:10,000 was selected for raster data. The vector data type, attribute and sources which are served through this application is shown in Table 2.

3.1.3 Database preparation

I. Spatial Queries

PostgrSQL with PostGIS add-on was selected as the database management system for development because PostGIS is capable of speeding data access using spatial index technology (Vera &Fabrizio, 2009). Common queries for information in web mapping applications take the types such as point, rectangle and spatial queries (Riccardo, et al., 2011). In the present application, point, polygon, spatial queries have been incorporated. In the present work only the Geospatial table facility of PostGIS was used (Yu, et al., 2012). Structured Query Language (SQL) is used to insert, update and delete data from PostGIS Database. PGAdmin III tool kit of the frame work for PostGIS was used as the front end application for PostgreSQL.

II. Vector

Though Grid format data are relatively easy to manipulate when compared with vector format data (Choi, et al., 2005), it is necessary for the selected datasets to be in Vector formats in order to acquire the capability to handle attribute data. Spatial indexing technology of PostGIS enables speedy GIS data access (PostGIS 1.5.1. Manual, 2012). In the present work all vector data which were in shape file formats were converted using PostGIS queries and then stored in PostgreSQL database to achieve the advantage of using spatial indexing capability.

III. Raster Data

In the present application georeferenced Google maps and scanned topographic maps are used as Tiles to keep the performance at best (Wang & Gong, 2008). Tiling for raster maps are also necessary for the incorporation of the functionalities such as projection, minimum and maximum scales etc., (Map Server Documentation, 2009).

3.2 Software Selection

Most of developers use open source software specifications and reuse of open source projects for the developments, because of benefits such as cost saving, fast bug fixing and speed of updates, usability and user-friendliness (Yu, et al., 2012, Baulos& Honda, 2006). By considering the speed of response time, user-friendliness and accuracy, HTML (Enge, et al, ,2003), JavaScript for frond-end application development (Choi, Engel, & Farnsworth, 2005), PHP according to recommendation of Adnan, Singleton, & Longley (2010) and XML for quicker data passing were selected for the WebGIS Application Development. GDAL libraries used to support raster data with high performance while CGI used as engine (Choi, Engel, & Farnsworth, 2005) to communicate among Web server, GIS sever and DB server components. In the present work which is targeting the use of open source capabilities mainly due to cost and support community advantages, selected MS4W(McKenna, 2012) which supports web development languages such as, HTML, PHP and CSS while providing recognition of AJAX and GDAL libraries.

3.3 Implementation

3.3.1 GUI Development

3.3.1.1 Components and sizes

The GUI design carried out a literature survey considering user preferences, and navigational techniques presently in use.

The survey revealed that the majority of applications has allocated approximately 60% of the GUI for map display. Commonly about 19% is used for the database interaction display while 4.5% and 14.5% are used for tool and permanent display areas respectively.

Using these values as a guidance and considering the study objectives, the present work made allocations in the main window. Accordingly the Table 3 shows the proportions selected while giving a prominence to the map display area.

In the GUI development, the main components Tab, Mapping Zone, Header, Footer, Menu and Tool Bar and their features such as colour, font, position were developed using CSS.

3.4 Function development

The built-in functionalities of Mapserver and OpenLayers (Open Source Geospatial Foundation, 2012) were utilized for the operations such as Identify, Viewing and Organizing Layers, Layer and Data selection, and Dataset Search. XML based MapBook (MapBook Reference Guide, 2012) is the configuration file for the User Interface, Source Layers, Services for passing data between pages and tools.

PHPwas selected as the programming language for the Database to Data base functions mainly because of literature recommendations and the support extended by the MS4W framework. Functions such as database interface development, user input data handling, output format development and output data handling, were developed using PHP. In case of database to database functions a user inputs are passed and processed by php through the services of Mapbook. The difference in the present application is that it deals with data having spatial references and therefore the querying requires the use of Mapbook facility. In the present application map to map operations are carried out with the help of openlayer facility of MS4W which consists of built-in functions such as Zoom, Pan, and Highlight. In the database to map functions the query results from PhP files are printed on Map using XML files. The functions "TurnOn" and "Zoom" which were developed using JavaScript perform the tasks of highlighting and zooming. When carrying out these activities, the data exchange between PhP and JavaAScriptis carried out by the Mapbook. Map to Database functions commence with the capture of information by clicking on map to perform query and calculate operations for printing outputs as text. Similar to the Database to Map functions, the methodology is to pass the Mapbook data using XML.

4 Testing and Verification

4.1 Functionality

After carrying out continuous testing during development, a primary testing of functionality was performed by systematically determining the criteria. Each main function of the application was checked for its flow and data. The next stage testing with users included checking the fulfillment of their requirements, and identifying the occurrence of inconsistencies. User understandability, and ease of operation with the familiarity of other software were also incorporated to this verification.

User satisfaction testing was done in three stages. Understandability, facility and flow of functions were under this user testing. In an initial attempt to evaluate the application for its user familiarity, testing commenced with a user-application interaction session without any external support.

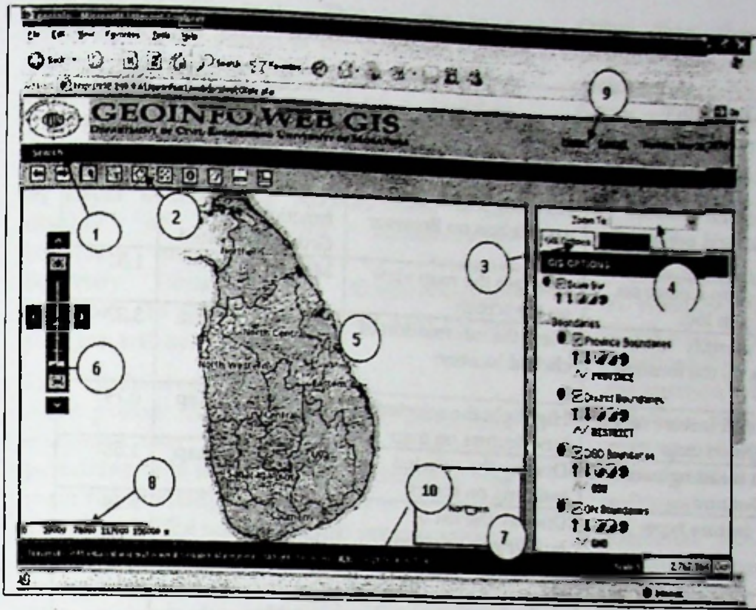
Recognizing the difficulties of very first time users, in the second stage, the application was tested providing a user manual that gives step by step guidance and graphical illustrations. During the third stage the experts and developers instructed and provided the users with guidance in addition to the user manual. This was done for the identification of error occurrences especially technical errors, when using the application even with a deeper understanding.

4.2 Data

Testing accuracy of outputwas evaluated with the help of a user group. In this exercise, the accuracy of information from database query, map serving and output computations were tested. Map serving accuracy was checked by using identify tool, by comparing the coordinates display in the footer and by comparing the neighbor and related features. Output computation accuracy was also tested with the capability to produce and display of summary information and feature location coordinates. Computation of polygon area was also checked for accuracy through manual

Table 3: GUI component and Their Sizes

Component	Weight	Functionality	Objectives
Header	13%	Display identity and key information	User attention with guidance on type and functionality
Footer	5%	Display cursor location coordinates Input scale change option	Quick and easy map display and location recognition
Tool Bar	6%	Basic and Commonly found software tools for mapping and database query	Easy and user friendly map navigation, measurements and information access
Mapping Zone	57%	Map Display and Map manipulation	Larger and better veiwing of maps and easy manipulation by user
User Preference Selection Zone	19%	Display the available list of layers Display the results as text and tables Enable User Inputs for selection	Parallel display of Information and commands



Legend

1	Search Query Menu
2	Tool Bar
3	GIS Options/Information Tabs
4	Quick Zoom Facility
5	Main Map Display Area
6	Map Zoom In/Out
7	Reference Map Display Area
8	Map Scale Bar
9	Header section
10	Map Coordinate Display Area

Figure 3: Main Interface Structure of the Application

verifications. Comparison of query results through the application and within the database was done with manual computations.

4.1 Performance

Response time was defined as the time consumed from lodging a user instruction to the point at which the user receives the desired output. Performance testing included 30 trials per test and then taking the average time between the first and the third quartiles.

5 Results

5.1 Features

Main interface of the GeoInfo WebGIS Application and its components are shown in Figure 3.

This application as its main purpose provides a user with information on buildings, roads and water streams within a spatial extent of 2.5 km^2 in the Moratuwa DSD. In this the building information are based on the address, number of floors, permanent or temporary status and the administrative boundary reference as attributes. Buildings are stored in the form of polygons. Building search is in two ways one is the direct search where a user can query based on the postal address. The other one which is the advanced search, provides the search based on any of the attributes. In the Direct Search of a building a user needs to carry-out the activities in the following sequence. Enter the full or part of the postal division name, 2) Select the relevant postal division from the displayed list, 3) Select postal area from displayed list, 4) Select the corresponding road from list, 5) Select the assessment number or house identification.

Road features are treated as lines. In the database, the attributes assigned to each road are the road type, width, length and the administrative boundary. The search facility in the application is similar to the buildings. Attributes of the water streams are name, type and length group.

5.2 User Testing

During user friendliness testing, it was revealed that at the initial stage, all users were able to perform the fundamental map functions such as Pan, Zoon and Quick Zoom. Most of the user sample indicated that the Query functions lacked user friendliness and required modifications. 75% of the sample failed to capture the use of query functions. After the incorporation of the User Manual with step by step guidelines, a major gap in capturing the usability was filled, but a number close to 75% of the user sample found difficulties in understanding a few of the tool operations. At the third stage with the introduction of instructor assistance the users were able to arrive at the desired outputs and this enabled the recognition of changes to functionality display, help functions, display arrangements, and user manual illustrations.

5.3 Performance

The response time of selected GeoInfo WebGIS functions are shown in the Table 4. Several performance issues related to access of

Table 4: Functionality Performance of Selected WebGIS Functions

No	Function	Function Description		Function Group	Response Time(sec)
		Input	Output		
1	Load Application	Enter the url on browser address bar and press enter	All components of the application on Browser	Entire functionality Group Activated	2.54
2	Pan	Drag and drop a place on map with pan tool	Changes the map view on the screen	Map to Map	1.51
3	Identify	Click on "identify" tool. Then click on the location on map	View the information of clicked location	Map to Database	3.37
4	Highlight on Map	Click on land feature name to highlight on map	Highlight the selected land feature on map	Database to map	0.79
5	Zoom to a Building	Click on a building name to zoom to Feature	Display the selected building on screen	Database to map	1.55
6	Display list of Buildings	Selecting feature type-building	Display the list of building in selected type	Database to database	7.64
7	Display list of Roads	Selecting feature type-road	Display the list of roads in selected type	Database to database	14.93
8	Display list of water streams	Selecting feature type-water stream	Display the list of water streams in selected type	Database to database	4.88

Table 5: Performance Issues and Identified Methods

No	Performance Issue	Details of Appearance/Recognition of Issue	Probable Causes
1	Non responsive situation when loading images	1. Frequent time outs when zooming the map using quick zoom 2. When a request is made to display the satellite image at a Zoom Level of 1:50,000, there is a no response situation	1. Database connection 2. Low efficiency/performance of server and the internet connection
2	Significant time consumption when loading data layers	1. More than 60 seconds consumed to load the building map 2. More than 60 seconds consumed to display list of buildings using in database to database function.	1. Performance of the server
3	Map refresh function behavior subsequent to highlighting	1. Highlighting a road feature on a turned on satellite image, then zoom the feature and pan the map. The highlighted make remains stationary even when the corresponding location has been panned 2. When highlight a land feature (building, road or water stream). highlighted location is not refreshed even when the map is zoomed to the Administrative boundary level using Quick Zoom function	1. Cache management 1. Server Performance

functionalities could be identified during the testing process and they are listed in Table 6.

6 Discussion

There were a number of issues that required solutions to arrive at full user satisfaction level. It was felt that the limitations of the tools and the design methodology both were contributing to these. Hence the issues are described with the aim of opening up discussion for the identification of solutions.

6.1 Geographic Search and Display

a) Building Search: Building location search has a limitation when there are two or more addresses in the same building. At this instance, the application limits its search even with the identify tool. This is due to a constraint in the design of the database which incorporates three methods to identify building (polygon), persons assigned to a building (point) and the building address (point which is the center of polygon).

b) Layer overlapping: Another issue is the display of overlapping administrative boundary polygons such as Divisional Secretary Divisions and GramaNiladhari Divisions. In an overlapping case, only the top polygon will be displayed.

6.2 Enhancements

As at present the GeoInfo WebGIS application enables a user to perform query information pertaining only to the data in the database. The main functionality used to Query is the "Select" Command. The used tools also provide options to use "Insert", "Update" and "Delete" for the incorporation of new data, modify existing data, or delete data. Future improvements to the tool can make such incorporations for better user functionality.

6.3 Testing

Performance testing which was based on time taken for execution considered only the time between first and third quartiles. The two extreme values were neglected because the network problems, client and server computer problems could result in exceptionally long response times which should not be attributed to the applications. Similarly, in most occasions, occurrence of cached data retrievals lead to very fast responses which also cannot be attributed to the application development.

It was noted that the database to database functions consume a comparatively longer time. During this activity it is necessary to display a large quantity of data and for this the application performs a query on PostGIS. In this connection the execution of a particular function requires a large number of computational steps to be performed at the server side. On the other hand, Map to Map functions appear as taking the shortest time. In this execution, built-in Javascript functions perform the actions with a very low number of steps. The above discussion reveals that the sever performance could be a major factor when a web GIS application is launched. A server with Windows XP professional Service pack 2 as the Operating System, and an Intel Pentium Dual CPU with a Processor speed of 2.0Hz and a RAM: of 1GB as hardware was used with the GeoInfo WebGIS application.

Other than these, it is also felt that the programming algorithms and coding of instructions should be critically evaluated for a better performance. Any future work should therefore carefully evaluate the present experience and develop applications for better performance over the web.

7 Conclusions

1. A WebGIS application for land and water application with good performance and functionality to query and display information with database to map, map to database, database to database and map to map operations was successfully developed and demonstrated using open source free software.
2. Literature recommendations on the use of HTML, PHP and JavaScript as programming languages, PostGIS for spatial database and MS4W as the operating framework for the WebGIS development provided successful guidance with very limited constraints
3. Non-responsive situations, high time consumption when loading data layers, map overlaying constraints when panning or zooming maps and delays during map refresh and server limitations were identified as performance issues in this case study
4. Testing of WebGIS applications would lead to better identification of shortcomings with a user group having prior training or with a good familiarity in the use GIS applications

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