EXPLORING THE CAPABILITIES OF OPEN SOURCE GIS PRODUCTS FOR LAND INFORMATION SYSTEM

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ABSTRACT

With the open source database and Geographic Information System (GIS) tools that are currently available, it is possible to build a robust yet low-cost land information system. This paper attempts to explore the role of new and emerging technologies, specifically GIS and internet technologies, for resource management, and a web GIS prototype to assist in the process of land information management.

Keywords: Land Information System, Geographic Information Systems, Open Source GIS, Web, Spatial Database

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1. INTRODUCTION

Land is required for various uses in both the urban and rural areas of all society. It is a major factor of production and a vital element in the socio-economic development of any country or society. Land records are very important because they form the basis for assignment of land titles. There is a need therefore for an on-line system that will simplify the registration and processing of land documents and providing integrated information about land and its resources, such as natural resources, topography, existing infrastructures, statutory requirements and the regulations that might apply to various developments on the land. A whole range of new Open Source GIS (OSG) initiatives started in 2002 which open up new possibilities for the use of OSG products in land administration systems. As these open source projects are not marketed as commercial products their distribution relies on communication between developer communities and they are often unknown to normal GIS users.

2. IMPLEMENTING LAND INFORMATION SYSTEM FOR LAND ADMINISTRATION

The methodologies of designing a Land Information System (LIS) tool for land administration include the "construction of spatial and non-spatial databases, development of information processing capabilities, installation of the appropriate computer hardware and software, implementing the organizational, procedural, and staffing changes needed to operate and use the system successfully'' (Huxhold and Levinsohn, 1995). According to (Ndehedehe, 2011), the suggested procedures include:

(a) *Ground Method*:

i) Creation of framework and national connectivity

ii) Establishing controls for each village boundary

iii) Detail survey of cadastral information and topographical information

v) Collection of other information required for land management

vi) Integration of topographical maps on small scale from large scale data

(b) *Digital Photogrammetry mapping combined with ground method*

2.1 Fundamental Elements of a Land Information System

It is important that when considering the development of an LIS, there are certain fundamental elements that should be considered early in the process. The Urban and Regional Information Systems Association (URISA) and International Association of Assessing Officers (IAAO), in their joint publication (URISA/IAAO, 1992) describe these four fundamental elements for a GIS-based cadastral mapping system as follows:

Geographic Control Data: Geographic control describes the coordinate system and points on the coordinate system for all data in the GIS. The coordinate system is used to reference where things are located. For example, a country may establish geographic control on major road intersections and property subdivision boundary corners. These coordinates would then be used in the base map data and cadastral information.

Base Map Data: Base map data are coordinates referenced to the geographic control for planimetric features that can be seen from an airplane. For example, rivers, lakes, streams, travelled ways, and railroad tracks may be included. The base map data would be coordinates for all these features.

Cadastral Data: Cadastral data are the graphic information describing parcels. These data include property corners, boundaries, and parcels of land. Typically, property corners are coordinates for points on parcel boundaries and identifiers for the corners, which allow cadastral information to be tied to attribute information. Boundaries are lines between corners, line topology that describes who owns land on either side of the line, and an identifier for the line which allows it to be tied to attributes. In cadastral information, parcels of land are polygons (closed geometric figures) and an identifier for the polygon that relates the parcel to attribute information.

Attribute Data: Attribute data are additional information about geographic control base map data, cadastral information, and other mapped features. For example, cadastral information contains lines with identifiers. Attribute data would have the line identifier and additional information about the line such as its bearing and distance as recorded in a deed. Attribute data are stored in a database.

The National Research Council (National Research Council, 1983) in its publication, Procedures and Standards for a Multipurpose Cadastre, described the same fundamental elements or data needs, when they identified the components of a multipurpose cadastre as follows:

1. A spatial reference framework consisting of geodetic control points;
2. A series of current, accurate large-scale base maps;
3. A cadastral overlay that delineates all cadastral parcels and displays a unique identifying number for each of them; and
4. A series of compatible registers of interests in land parcels keyed to the parcel identifier numbers.

2.2 Capacity Building Needs for Land Information Management

As global concerns heightens as to the need for automated land information systems in Africa and the need for computerized LIS, capacity building should form one of the most fundamental aspects of this process both in the public and private sector for very many reasons. The most important reason has to do with the involvement of end users of the computerized LIS in the 'systems analysis' phase. Automation of LIS should initially be based on the automation of existing procedures for improved efficiency rather than the introduction of completely new processes and procedures that may face stiff resistance to change from the beneficiaries.

The end users of automated LISs should be able to make meaningful contributions and suggestions during the systems analysis phase that will guide and drive the process of software development. To do this, they need to have first of all acquired the skill and some level of competence in the use of computers which might lead to increased receptivity to these new ICT based products (Kakulu, 2003). Public sector practitioners are in urgent need of capacity building initiatives both from the government and the international community. Capacity building by way of skills transfer, software development and hardware are required to foster automated LIS systems.

3. SPATIAL DATABASES FOR LAND INFORMATION MANAGEMENT

With the development of spatial extensions for most database software products, huge amounts of map data can be efficiently stored and managed in geodatabases. Oracle Spatial is the best known platform for spatial databases, but open source alternatives are growing in popularity. PostGIS is an extension to the PostgreSQL object-relational database system which allows spatial objects to be stored in the database (see Figure 1). The strength of PostGIS is that it has become the standard spatial database for all open source GIS tools (Ramsey, 2007). Also MySQL has included spatial functionality in its database core so that it can store geographic features. Both MySQL and PostgreSQL with PostGIS are excellent database products, but PostGIS comes closer to the sophistication of Oracle Spatial when it comes to topology and geometry support.

The installation and use of open source database products has become easier over time. In fact, PostgreSQL and MySQL are easier and faster to install than Oracle and occupy less memory and disk space. While in the past the databases had to be managed from the command prompt through SQL commands, Graphic User Interfaces (GUI) such as PgAdmin for PostgreSQL have now been developed so that database administrators can easily add columns, set relationships between tables and manage security settings.

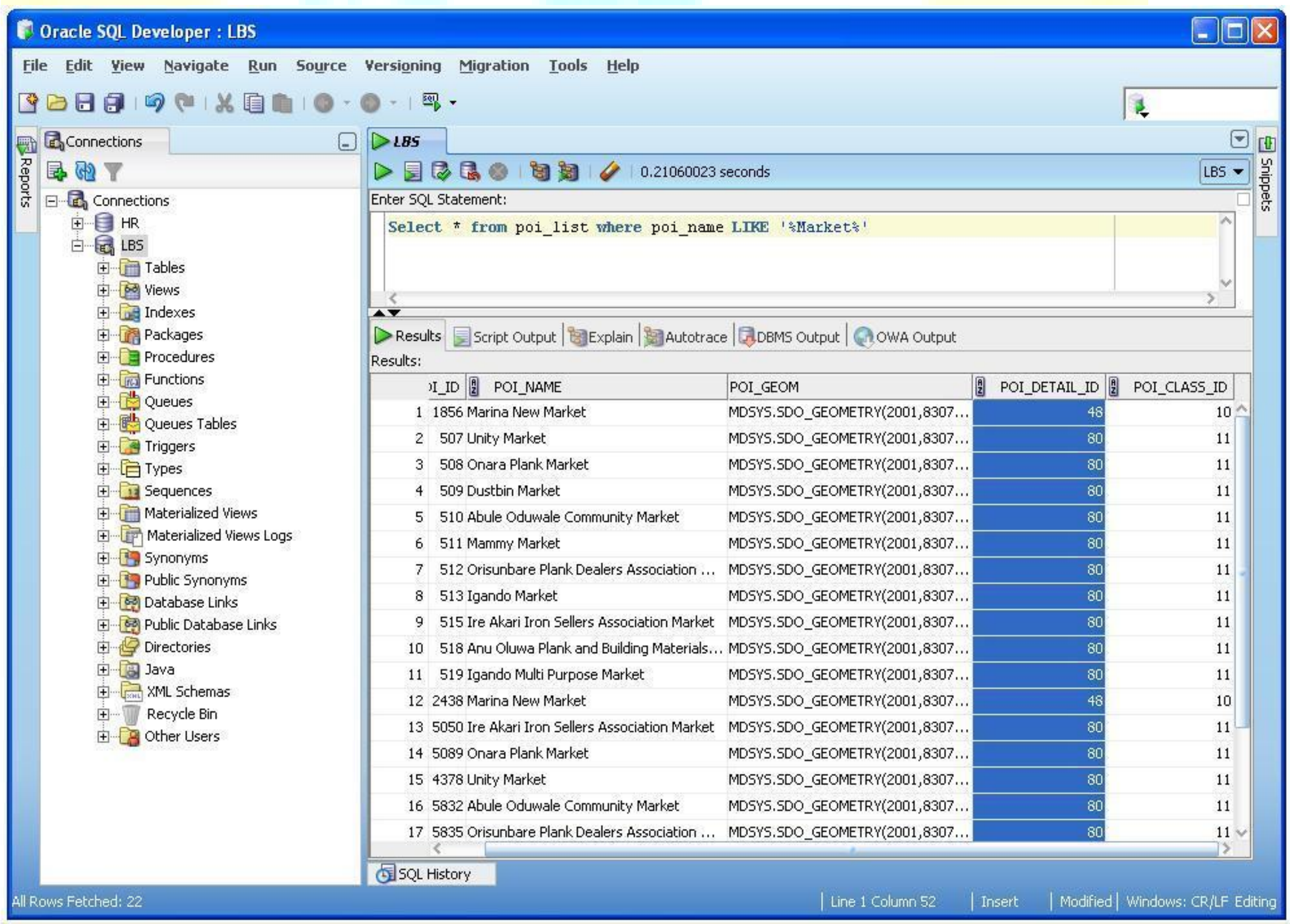

Figure1: Point of interests in the oracle SQL developer (adapted from Ndehedehe, 2011)

Tasks such as topology checking and spatial analysis that were traditionally handled by GIS desktop software can now be managed efficiently through the spatial database functions that PostGIS provides. With the GEOS geometry engine, PostGIS users can calculate the area of polygon features, convert linestrings to polygons, and perform overlays such as Union, Difference and Intersect. The spatial relationships between geometries can be tested with functions such as Contains(), Distance(), Crosses(), Overlaps(), Touches(), and many others.

4. OPEN SOURCE GIS TOOLS FOR LAND ADMINISTRATION SYSTEMS

Even though the spatial database functions can take over many of the data analysis and processing tasks, desktop GIS products are still needed to create, visualize and maintain spatial datasets. Land administration systems vary in their software requirements, but a number of minimum requirements can be identified.

4.1 Typical GIS Needs for Land Administration Systems

4.1.1 Coordinate Systems

The software must support the geographic and projected coordinate systems required for cadastral maps. Cadastral agencies will likely use only one standard coordinate system for cadastral datasets, but when data from different coordinate systems are combined, transformations or on-the-fly projections are needed. In most open source GIS products, the technology required for projections is drawn from the common class libraries PROJ4 (for software written in C or C++) and GeoTools (for the Java based GIS products). Both PROJ4 and GeoTools support a wide range of map projections.

4.1.2 Editing Tools and Topology Support

To create and maintain accurate cadastral maps, the software must have functions to create polygons, lines and point features, and to edit the geometry of polygon features by adding/deleting/moving vertices. Functions for cutting and merging of polygons are needed for parcel subdivisions and consolidations. Additional editing options such as clipping and buffering are useful when creating buffers along roads or around protected areas. To ensure the accuracy of cadastral boundaries, the mapping software must have functions to create and maintain correct topology. When creating features, the user must be able to set a snapping tolerance and snap to existing features. Adjacent polygons should share common boundaries and during cutting and merging of polygons, correct topology must be maintained.

4.1.3 Raster Data

When orthophotos or satellite images are used for on-screen digitizing or verification of parcel boundaries, the software must support the raster format of the images to be used. Most GIS software products support common raster formats (TIFF, JPG), some support satellite image formats such as SPOT and Landsat and have image processing functions such as rectification, filtering and image classification.

4.1.4 Compatibility with Surveying Data

The software should have options to import and process field data from GPS, total stations and handheld PDAs. Some GIS products have functions to connect to GPS devices and download data from them.

4.1.5 Presentation and Output

The software must have the functionality to produce cadastral maps as required by the cadastral organization, including the required point and line symbology, additional map elements such as the legend, scale bar and north arrow, and support the printing or plotting on A0 format or custom paper size.

4.1.6 Database Connection

For most purposes, it is more efficient to store geographic data in server-based geodatabases instead of in local file structures. When used for a considerable volume of map data, or if multiple users need simultaneous access to the same dataset, the software must support connections to directly access and edit map data stored in external databases.

4.2 Open Source Desktop GIS Products

There are many open source GIS tools available as considered by Pieper (2008) but the few products that are discussed here are considered most useful in land administration systems.

4.2.1 ILWIS

The Integrated Land and Water Information System (ILWIS) is a PC-based GIS & Remote Sensing software, developed by ITC up to its last release (version 3.3) in 2005. ILWIS comprises a complete package of image processing, spatial analysis and digital mapping. It is easy to learn and use; it has full on-line help, extensive tutorials for direct use in courses and 25 case studies of various disciplines

4.2.2 POSTGIS

PostGIS adds support for geographic objects to the PostgreSQL object-relational database. In effect, PostGIS "spatially enables" the PostgreSQL server, allowing it to be used as a backend spatial database for geographic information systems (GIS).

4.2.3 TatukGIS Viewer

The free TatukGIS Viewer opens most GIS/CAD and raster image file types and most ArcView, ArcExplorer, and MapInfo projects. Besides just opening and viewing files, the Viewer supports an extensive list of features including visual layer properties control, legend control, thematic mapping, spatial and attribute querying, custom labeling, on-map measurements, hyper-linking, PDF export and much more. The user interface is available in 16 languages.

4.2.4 gvSIG

This is an open source GIS product developed in Spain by IVER Technologías in cooperation with the Valencian government and the Jaume I University of Castellón since 2003. The name gvSIG is a Spanish abbreviation that stands for *Generalidad Valencia Sistema de Información Geográfica*. Once accustomed to the interface, gvSIG is a user-friendly GIS product for which many translations are available. The combination of editing capabilities, platform independency and support for PostGIS as well as MySQL database connections makes gvSIG a highly useful GIS base for land administration systems. According to the gvSIG Desktop Roadmap (gvSIG, 2008) a topology extension that would allow users to apply topology constraints to spatial datasets is under development. More editing tools including cutting and merging of polygons are also planned to be released soon. In March 2008, a lightweight version of gvSIG has been released that can be used on mobile devices (PDAs). It supports shapefiles, ECW, WMS and images and is able to connect to GPS receivers. Currently, only the visualization of layers and the generation of GPS tracklogs and waypoints are supported, but functions to create and edit geometries are planned as well.

4.2.5 OpenJUMP

JUMP (JAVA Unified Mapping Platform) was initially developed in 2002 by Vivid Solutions Inc. on initiative of the British Columbia Ministry of Sustainable Resource Management and evolved into a platform independent GIS with strong editing capabilities. JUMP uses the Java Topology Suite (JTS) which implements the OGC Simple Features Specification for geometric operations. Compared to other open source desktop GIS, JUMP has quite advanced editing tools, including cut and merge polygon features. It can also check for basic topology errors such as self-intersecting polygons. JUMP has a warping function that can be used to rubber-sheet a vector layer using a bilinear interpolation method. Even though the editing and statistical functions are impressive and JUMP continues to be a very useful desktop GIS, there are down sides as well. JUMP has little support for coordinate systems, as it does not use the GeoTools library for projections. Problems with the memory allocation make it difficult to load and edit large map layers or PostGIS tables in JUMP. Apart from OpenJUMP, there is SkyJUMP, PirolJUMP and DeeJUMP all with a similar interface but each having its own additions. With the different versions and sub versions of JUMP it is hard to get a clear overview of its capabilities, but this maybe solved when a documented public version 1.2 of the OpenJUMP software is released.

4.2.6 MapGuide

MapGuide Open Source is a web-based platform that enables users to quickly develop and deploy web mapping applications and geospatial web services. MapGuide features an interactive viewer that includes support for feature selection, property inspection, map tips, and operations such as buffer, select within, and measure. MapGuide includes an XML database for managing content, and supports most popular geospatial file formats, databases, and standards.

4.2.6 Map Publisher

MAPublisher Software for "final copy" (lite version for free).MAPublisher 7.5 combines the best features of GIS with the powerful design environments of Adobe Illustrator CS2 and CS3 to enable native GIS data files to be used as a base for cartographic production. Designed for use with Adobe Illustrator and some other professional graphics packages.

4.3 Open Source GIS Servers and Web GIS Services

Development of the web and expansion of the internet provide two key capabilities that can greatly help geoscientist. First the web allows visual interaction with data. By setting up a web server, clients can produce maps. Since the maps and charts are published on the internet, other clients can view this updates, helping to speed up the evaluations process (Helali et al., 2002).
When it comes to web servers and server operating systems, the use of open source software has already been widely accepted. Research shows that two-thirds of European companies choose open source systems like Apache, Tomcat and Linux over proprietary alternatives (Ghosh, 2006). Also land administration systems can benefit from the use of open source server software. Especially in the area of internet mapping and web enquiry systems, OSG products are increasingly popular

GeoServer, MapServer and Degree are open source map server products focusing on internet mapping applications using OGC webGIS standards. They are server-based “map engines” to display spatial data (maps, images or vector data depending on the OGC web service) over the internet to users based on their requests.

4.3.1 Map Server

MapServer is a popular Open Source project whose purpose is to display dynamic spatial maps over the Internet. In its most basic form, MapServer is a Common Gateway Interface (CGI) program that sits inactive on your Web server (Ndehedehe, 2011). The most basic functionality of MapServer is its ability to read in a map file and create an image showing the map. When a request is sent to MapServer, it uses information passed in the request URL and the Mapfile to create an image of the requested map. The request may also return images for legends, scale bars, reference maps, and values passed as CGI variables. A simple MapServer application consists of; Map File, Geographic Data, HTML Pages, and HTTP Server. And indeed, MapServer has proved to be a very mature and reliable product to distribute maps from GIS data sources over the internet through the Web Map Services (WMS), web coverage services (WCS) and other Open Geospatial Consortium (OGC) interoperability standards.

4.3.2 Location Based Services

Location based services (LBS) denote services provided to mobile users according to their geographic locations. They are generally information services accessible through mobile phones, Personal Digital Assistants (PDAs) or other mobile devices. The main function of Location Based Services (LBS) is the possibility to retrieve information about the features in the proximity of a mobile user, utilizing positioning techniques. A Location based service for Lagos state was developed using Mapserver as the GIS server. A platform was been designed to make queries to the LBS (see Figures 2 and 3). This platform contains the main functionalities of LBS: search possibilities and map rendering with additional features such as the routing of roads, places and points of interest.

Figure 2: The complete map frame with reference map displayed on a web browser

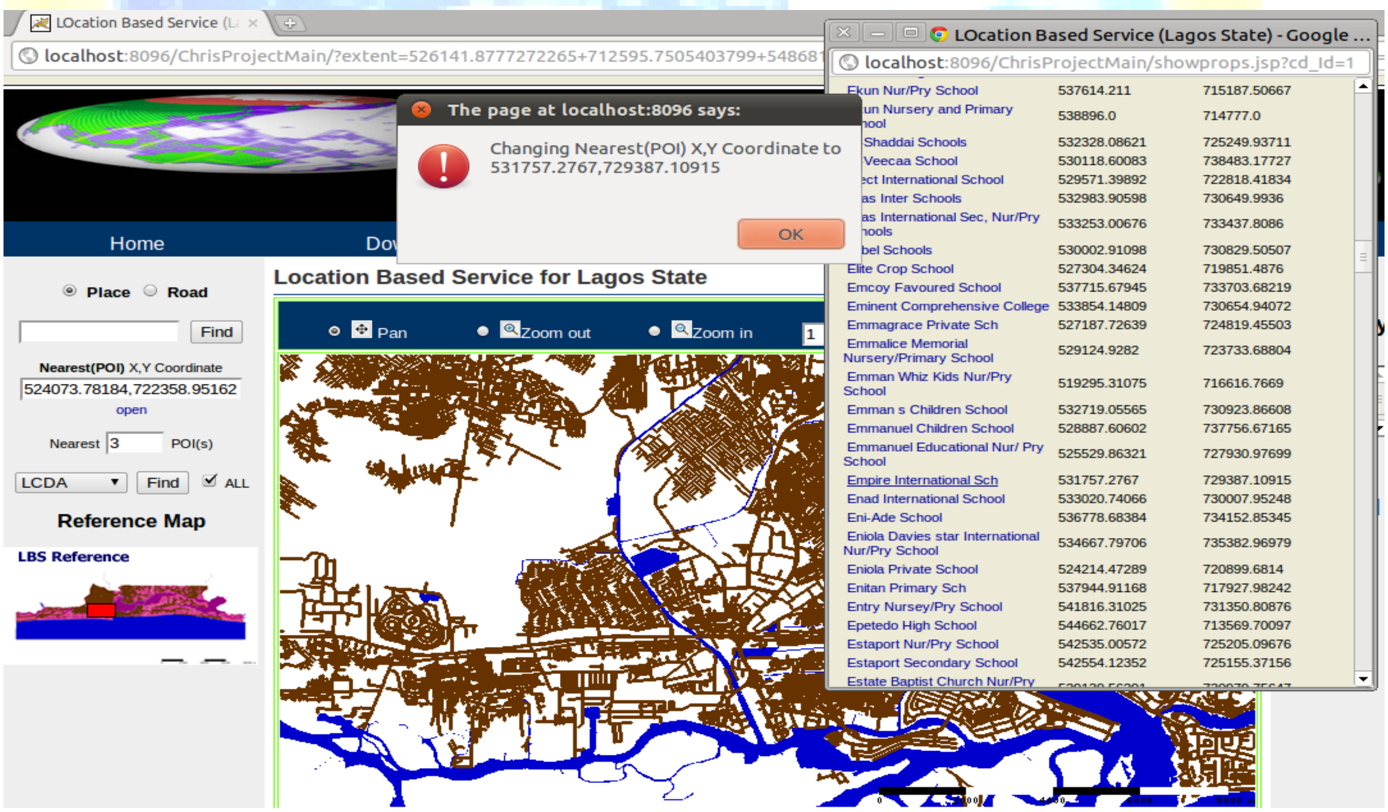

Figure 3: Map Frame Showing Coordinate Listings of Various Point Of Interest Locations

5. CONCLUSION

The need for GIS or automated land information systems cannot be overemphasized. In Africa for example, there are already leading examples of geographic information systems in Nigeria like the Abuja Geographic Information Systems (AGIS) and the current efforts at automation in Accra – Ghana. Capacity building is one of the most crucial components of achieving a sustainable LIS in Africa.

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