International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:9, No:3, 2015

Building an Interactive Web-Based GIS System for Planning of Geological Survey Works

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***Abstract*—**The planning of geological survey works is an iterative process which involves planner, geologist, civil engineer and other stakeholders, who perform different roles and have different points of view. Traditionally, the team used paper maps or CAD drawings to present the proposal which is not an efficient way to present and share idea on the site investigation proposal such as sitting of borehole location or seismic survey lines. This paper focuses on how a GIS approach can be utilised to develop a web-based system to support decision making process in the planning of geological survey works and also to plan site activities carried out by Singapore Geological Office (SGO). The authors design a framework of building an interactive web-based GIS system, and develop a prototype, which enables the users to obtain rapidly existing geological information and also to plan interactively borehole locations and seismic survey lines via a web browser. This prototype system is used daily by SGO and has shown to be effective in increasing efficiency and productivity as the time taken in the planning of geological survey works is shortened. The prototype system has been developed using the ESRI ArcGIS API 3.7 for Flex which is based on the ArcGIS 10.2.1 platform.

***Keywords*—**Engineering geology, Flex, Geological survey planning, Geoscience, GIS, Site investigation, WebGIS.

I. Introduction

SINGAPORE is a small country and with an increasing population, the government has embarked on developing an underground master plan to ensure that major underground and above ground spaces are synergized and optimized to create more space for the country and citizens to enjoy. Geological information is an essential data require for any building and civil engineering projects i.e. used in the planning, design and construction stage, especially for underground development projects like cavern and tunnels. Since 2012, the Singapore Geological Office (SGO) of Building Construction Authority started to collate and centralise the borehole data obtained from various public agencies of Singapore. Geological survey works were also initiated and carried out at study area by SGO to obtain geological information for the users agencies to initiate studies on the potential underground usage at the identified areas, and study how best they can be connected and integrated with the aboveground land use.

The scope of geological survey works is more comprehensive compared to a typical geotechnical site investigation works for building project. For example, boreholes are drilled to a deeper depth of 200m and seismic survey lines are planned to identify major geological structures and discontinuities at the study area. The geological survey works also include specialized tests like borehole televiewer, PS-logging and hydraulic fracturing test, carried out in the deep boreholes. In view of the scale and scope of geological works are more involved, it is essential to have a good support decision making tool for planning of geological survey works. The traditional approach of planning geological survey works used paper format such as geological map, historical borehole report, aerial photos, etc. The task of gathering and integrating these data require significant effort and time as the geological information are in hard copy or PDF format, which the user i.e. geologist is unable to query/analysis the data quickly [1]. As planning of geological survey is an iterative process which involves planner, geologist, civil engineer and other stakeholders, it is clear that traditional approach is not efficient and productive. This paper focuses on how a GIS approach is utilised to develop a support decision making tool for use in planning of geological survey works.

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II. GIS Application to Geological Survey Works

Geographic Information System (GIS) is used for spatial data management, visualization, analysis, and decision-making support. It provides the means for effectively integrate spatial and tabular data obtained from numerous sources and allows user to visualize, analyse and understand the data in the form of maps, reports, tables and charts spatially [2]. From application point of view, GIS is a map link to the database. User can rapidly gather all the information associated with the feature by simply click on the map. The developed drawing tools and the GIS-based maps will greatly assist the user in understanding the situation and in storytelling, which improves communication between different teams, departments, disciplines, organizations and the public [3].

The geological survey data have spatial attributes, which can be located at a point or a line or a polygon in a map, and integrate with multi-source data like existing boreholes, geological map, services map, photos, SI reports etc. Themes of data, known as “layers” in GIS, can be readily combined to provide a wealth of information about a site and it can be added or removed from a base map by turning the layers ‘on’ or ‘off’ [4]. User can interactively make query using criteria and the analysis results will be displayed immediately on the map. Using GIS tools, existing geological information can be retrieved easily and new boreholes/seismic survey lines can be positioned such as to avoid locating too close to existing services.

The cost of purchase a professional GIS standalone software license for use, however is quite high. As such, it is not cost effective to purchase the necessary hardware and software required for everyone to use the GIS standalone software. Further, many users are not well versed in GIS to view/analyze geological data. Fortunately, there are mapping applications available on the web such as Google Map, which is freely available and easy to use as users are generally familiar with the navigation and interaction options in using such web mapping application [5]. Considering the above, the cost effective way for SGO is to place GIS on the Web, named as Web GIS, whereby users need a web browser like Internet Explorer, Chrome, Firefox, etc. to access and use the geological information anywhere. This will mean that SGO require one GIS suite software license and one computer to host the GIS software and data. This will greatly reduce the investment cost for both software and hardware [6]. The other major benefit is that it allows more users who need geological information in their daily works to use the system.

The following section described the framework of building an interactive web-based GIS system using ESRI ArcGIS platform and development of a web-mapping application prototype tool for planning of geological survey works.

III. Framework of a Web-Based GIS System for Planning of Geological Survey Works

During design of the GIS system, there are some GIS issues need to be studied and addressed such as how to integrate pre-existing multi-source and multi-format data, how to access geological information and other relevant information for project analysis, how to interactively propose borehole location and seismic survey lines on the map for discussion, etc. In order to address these issues, the authors proposed an interactive web-based GIS system framework, which comprised of a three-tier architecture: data tier, server tier and client tier (see Fig. 1).

A. Data Tier for Data Integration

To support geological survey planning, the first step is to integrate existing information and the surrounding geo-physical environment. There are numerous source and types of data such as existing borehole data, 2D/3D seismic-reflection data, geological map, topographic map, DTM, satellite image, aerial photograph, gas/water pipelines plan, telecommunication cables plan, site investigation reports, etc. Some of these data are in digital format and some are scanned map. The raw data formats are different also. For example, topographical data are in ESRI Shapefiles, boreholes data are in AGS or PDF format, soil profile cross-sections are in CAD or PDF format, etc.

Based on this framework, the integrated geo-database is built using ESRI Geodatabase technology. The existing borehole data, geological data, topographical data, satellite images, aerial photos, utilities data and as well as buildings, roads, water bodies data required some form of processing and conversion. These data are managed in the integrated geo-database using ArcGIS ArcCatalog. The site investigation reports in PDF format and scanned photos, soil profiles are indexed using a file reference system.

When integrating the various data on the maps, some readily available datasets are in different coordinate system such as Universal Transverse Mercator (UTM). To make data coordinates system consistent, all datasets of different coordinate system required to be converted to a common coordinate system (i.e. SVY21) and stored in the integrated geo-database. There are some scanned map/soil profile datasets, which do not contain spatial reference information (either in the file or separate file). As such, geo-referencing is required to make use of such datasets with the basemap.

The borehole locations are plotted and overlay on to the base maps such as geological map, street map, topographical map and satellite image map. The base maps comprised outline of Singapore, roads, buildings, parks, water bodies, land lots, address, satellite image, geological map, aerial photograph, DTM, etc. The relevant reports, soil profiles, etc. are attached to the corresponding borehole location or a feature by creating hyperlinks based on the index using ArcGIS ArcMap.

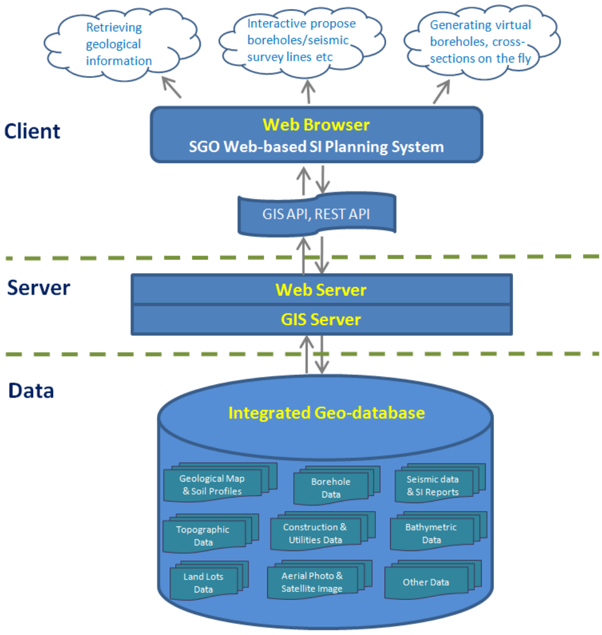

Fig. 1 Framework of SGO web-based system for geological survey planning

B. Server Tier for Publishing Geological Resources and GIS Functionalities

The server tier provides the platform to publish GIS resources such as maps, cross-sections, borehole information, geo-processing tools over the network and host web-based GIS application to serve the users across the web. In this framework, SGO used ArcGIS Server as the GIS Server. The GIS Server not only provide access to particular GIS resources such as maps but also provides access to GIS functionality, which the resource contain like interacting with the map to find the deepest borehole by specifying the interest area to get the relevant geological information. To address the viewing of geological information and retrieving efficiency issue, the GIS Server published base maps as cached map services. This can be addressed by pre-clipping static image at specific scale level to the base map. By returning an image tile from the cache takes the server much less time than drawing the map image on demand. The map resolution can change depending on the user interaction with the browser. The Web Server is referred to the software which helps to deliver web content and access through internet. The most common use of web server is to host websites. In this framework, the Web Server is used to host the interactive web-based GIS application. Microsoft IIS is chosen as the Web Server.

Under this framework, the server tier is responsible for receiving the client tier's request and to process it, including retrieve data from database and create the content (map or attributes). After generating the content based on the request, the content is send to the client tier. The content from server side will be displayed at the client tier for users' viewing or further interactive operation.

C. Client Tier for Accessing Geological Resources and Interactive Operations

The client tier is used to support users for accessing and retrieving or querying the geological information based on some set criteria. It also provides the platform, which allows the users to interactively propose borehole locations or seismic survey lines freely via web browser.

In the client tier, the web-based GIS system for geological survey planning is developed using Flex API for ArcGIS Server. The user interface is implemented at this tier, which provides the tools to help in the decision-making. The web browser allow the user to explore the map, analyse geological information and propose boreholes/seismic survey lines by accessing the map resource hosted on the server tier. The development toolkit used is Flex Builder 4.6. All essential functionalities like map navigation, searching boreholes by address, viewing and retrieval of borelogs, geological information, google street view and interactive tools for proposing borehole/seismic lines are also provided.

IV. Developing the Prototype

Based on the framework discussed above, a prototype of the interactive web-based GIS system was developed. The implementation of the prototype involved first by developing a technical proof-of-concept, which need to be interactive for geological survey planning that can support users' ideas and assist decision-making during discussion. The prototype is used by geologists from SGO in their daily works. Other users like engineers outside SGO also benefited as they used the prototype system in their course of work to check and retrieve geological information. Figs. 2-4 show some capabilities of the prototype.

Fig. 2 showed the user can access and switch among the various layers such as geological map, satellite image, topographic map for viewing. User also can query the borehole attributes and retrieve the borehole log on the fly, or to obtain the geological information by clicking the geological unit on the geological map. This is an essential functionality to support the users to obtain quickly geological information.

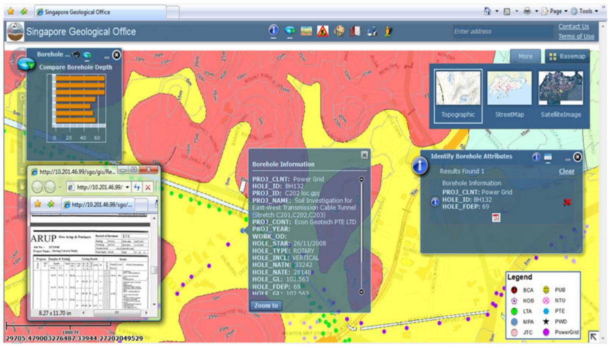

Fig. 2 Accessing and retrieving geological information

Fig. 3 showed the user can select the boreholes to check the boreholes' depth and present them in bar chart. This functionality is useful for the users to find out rapidly the depth of the boreholes and source of the data.

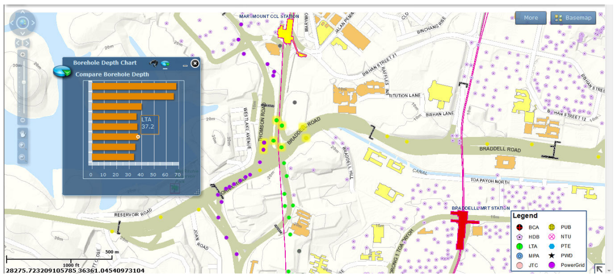

Fig. 3 Displaying borehole termination depth

Fig. 4 showed the user can draw points, lines and polygons on the map directly, label them using text, find out the co-ordinates, and calculate geometry length and areas etc. very quickly. The Google Street View is also integrated in the system, which allows the user to check the site environment and conditions during the planning stage.

Fig. 4 Use interactively for proposing boreholes and seismic survey lines

V. Conclusion

The developed prototype system has demonstrated an effective use of GIS in developing an interactive web-based system which provides geological information and tools to assist users like geologists in their decision making and planning of geological survey works. The authors design the framework of this interactive web-based system based on GIS technology. The system can be further enhanced in the future such that the user will be able to generate virtual borehole and cross-section on the fly based on the user's interaction in the web browser.

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