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Development of a prototype for Spatial Decision Support System in risk reduction based on open-source web-based platform

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Abstract:

This paper presents the development of a prototype for a Spatial Decision Support System (SDSS) in risk reduction based on available open-source geo-web platforms. The main purpose of this system is to find a way to make SDSS more practical and user-friendly, thereby reducing the cost of and time required by the project.

Malczewski 1999 [1] describes SDSS as an interactive computer-based system designed to use spatial information to support a decision maker with a final solution based on the semi-structured spatial problems. A SDSS is usually composed of users, decisions (also known as "alternatives") and criteria (or "indicators") which represent the costs and benefits of each alternative.

We will begin by demonstrating the modularity of SDSS platform for risk reduction. SDSS consists of different components or modules. In this specific research, the modules are Input module, Risk module, Visualization module (which uses GIS tools) and Decision Module. Each of these modules is equipped with different functionality and analytical process and will be used by different organizations such as spatial planner, geologies, engineering for risk reduction mitigation, local authorities, etc. This means that the whole SDSS can benefit from a collaboration platform between all organizations, stakeholders and their responsibilities that are involved in decision making and risk reduction. In addition, the system is planned to apply Multi Criteria Decision Making (MCDM) to evaluate the most appropriate alternative options in Decision Module.

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Keywords: SDSS, MCDM, Open source, Web-based, Risk management

1. Introduction

Nowadays automation and web-based decision support systems become more practical with development and capabilities of World-Wide-Web, distributed computing and computer human interaction. Decision support system (DSS) proposed by Simon [2] in mid-1960s. The major application of DSS is accessing and analyzing of database for supporting single or group decision making. Power [3] summarized DSS to progresses of model-driven, data-driven, communications-driven, document-driven and knowledge-driven DSS. Data Base Management System (DBMS) can store and manipulate spatial data, query and analytical modeling while a Model Base Management system (MBMS) performs a task which is analogue to the function of DBMS and instead of storing data, storing the element of elements of models. Our SDSS contains both DBMS and MBMS. Beginning in about 1980, development of Spatial Decision support System (SDSS) in parallel with Multi Criteria Decision Making (MCDM) is introduced by Malczewski [1]. Today SDSS uses in different disciplines and various applications such as spatial planning, risk management and etc. Furthermore application in the field of Planning Support System (PSS) is offered by Geertman and Stillwell [4, 5].

Basically a SDSS has the following components as shown in Figure1: Geographic Data Base, Model Base, Dialog Generation management which is related to visualization, communication between users and the rest of system as well as user-friendliness [6].

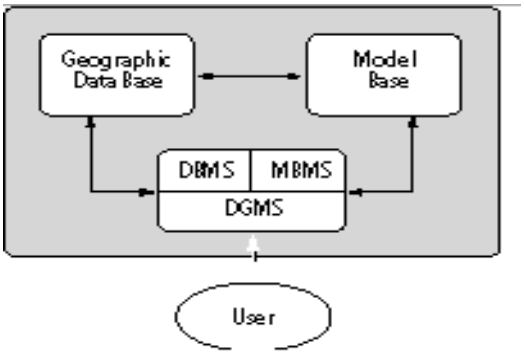

Figure 1: Components of SDSS proposed by Malczewski [6]

We can also refer to many studies regarding the use of GIS in Decision support systems [7, 8, 9, 10] naming as Special Decision Support System. Some has mentioned that [7] SDSS is not a GIS; it is based on spatial data and GIS. GIS offers tools for storing, visualization and querying while SDSS uses GIS functions to find a solution for a specific problem by analytic and probabilistic approach.

There is a question if different decision makers make different decisions with different types of GIS displays such as visualizations and communication effectiveness? SDSS has a positive contribution for the decision makers if they can reach to the solution faster with more accurate solution unless they would prefer the pencil-paper version instead of computerized solution. As a result of these studies [7, 10], time and accuracy in visualization plays an important role in decision making.

Several available SDSS are utilized in academic works or they are just prototypes and conceptual frameworks. Uran and Janssen [10] reviewed some experiences of SDSS from Netherlands and remarked that the reasons for SDSS not being used after the implementation are due to lack of user-friendliness, the system's complexity and unclear navigation through the system for the users. In addition, many visualization methods (Graphs, tables, maps and changes over the time) were not applicable, and the performance measured by accuracy and time was not well managed. As a result, the most important purpose of SDSS is that whether decision makers accomplish better their decisions with the SDSS or without.

2. System Modules

As mentioned before, the system is composed of different modules such as: Input Module, Risk Evaluation Module, Visualization Module and Decision analysis Module. Each module has its own functionality and its sub-modules that they lead to final decision making. The important phase of SDSS is to find a way to link the available modules to each other and to define the user management for different user interactions and user interfaces. We will explain each module shortly and mostly focus on Decision module.

2.1 Data Input

This module is related to data preparation and data upload to the system. It consists of the sub-classes as follows:

- Define the study area
- Upload Hazard map (which basically is a raster map)
- Upload Element at Risk (which is vector map or SHP file)
- Input Vulnerability data or create Vulnerability Table

2.2 Risk evaluation

This module is one of the most calculation modules in the system where can be done in PostGIS or using in Web Processing Services (WPS). It contains following two sub- modules: Loss estimation and Risk analysis module. Those are working closely with each other. More information on literature and calculation through the risk analysis for natural hazard can be referred to [11, 12].

2.3 Visualization

As we discussed, visualization plays a significant role for decision makers to make the decision. This module can be subdivided into different classes called as widget: Map widget (to display different Raster and Vector maps), Data view widget (to demonstrate tables and grids and query on them), Risk widget (to visualize risk in different period of time) and Alternative widget (for sketching alternatives and visualizing all updated alternatives). Each one has different interfaces and interactions for displaying the data (maps and tables) and query of a specific request in the system and current module. All these widgets have dependency to each other, for example, Data view widget cannot work without Map widget.

2.4 Decision analysis

This module can be described as a set of procedures to analyze the decision. Decision making analysis is comprised of Decision problems that lead to Multi-Criteria Decision Making (MCDM). MCDM is choice and prioritization and defined based on Alternatives, Value, Criteria and Weights on Criteria. MCDM can be classified as Multi Objective Decision Making (MODM) and Multi Attribute Decision Making (MADM), sometimes it can be referred to Single or Group decision making and based on the methods, it can be achieved by certainty or uncertainty [13]. MODM typically uses when the alternatives are concrete and MADM are useful for discrete alternatives. Moreover, in GIS perspective, we can say that MODM are done for raster data and MADM for vector data. In this work we will use the term MADM as MCDM. Malczewski [14] stated that the most works on MCDM are based on single decision making. Nevertheless, group decision will give us benefits in this research. It depends if each group has different choices of decisions [15] so we have to decide if they want to have the judgment separately by separate models or one model for all decision makers with standard Criterion.

Decision making processes are involved in three phases: Intelligence, Design and Choice [6]. Decision making is started by intelligence phase for recognition of the decision problems and examining the conditions. In the next step, development of the alternatives and assigning the variable by decision makers to each alternative are identified. Finally the last phase evaluates the decisions by indicating a weight to each criterion and ranks the alternatives to choose the best one.

There are many methods available for MCDM. These methods can be divided to deterministic, fuzzy and stochastic. When there is certainty in the alternatives, we go for deterministic and if uncertainty is apparent, fuzzy and stochastic models are useful. MCDM are introduced by different methods like [13] Weighted sum Model (WSM), Weighted Product Model (WPM), Analytic hierarchy process (AHP), Revised AHP , Elimination and Choice Translating Reality (ELECTRE), TOPSIS (for the Technique for Order Preference by Similarity to Ideal Solution) and etc. As a beginning it is planned to apply the most common and easiest way of MCDM known as AHP. Afterwards, we can integrate TOPSIS and Fuzzy methods to the study and compare the results.

3. Technology and system architecture

The enterprise application is usually employed to a Three-Tier Client/Server Architecture. This architecture provides three layers where each layer deals with different level of responsibilities [16]. It is intended to use three-tier architecture in our web-based SDSS. Figure 2 shows the composition of them. The top tier or presentation layer is part of the user interface, the Middle tier is the core of the system for business logic and the bottom tier handles the data storage. One of the advantages of this architecture is easier to make changes in database layer without influencing the other layers.

Furthermore this SDSS should be developed by Open-Source-Geospatial technologies. An open-source is distributed as the source codes that are available to public for use and modification. OSGeo (Open Source Geospatial foundation) which dates back to 2005 is a nonprofit foundation that supports development of the Open-Source-Geospatial software [17].

One of the proposed architects for the SDSS is OpenGeo (currently Boundlessgeo) [18]. OpenGeo is an open source platform that comprises of Geoserver, PostGIS and Javascript client side (OpenLayers, Geoext based on Ext JS) and suits our proposed three tier architecture. SDSS employs HTML, JavaScript and CSS on the client side with a combination of PHP scripting language and a PostGIS database on the server side. In addition, the maps are provided by OpenLayers as well as all the data are stored in PostGIS database on the server.

Analytical components for risk will be done in database and decision analysis calculations are carried out in JavaScript in the client side. Finally the results are stored into the database. These components are included: User registration information into the Database, Alternatives, Evaluation criteria, Weighting of criteria and Final ranking.

Additionally Geonode [19] can be used in the application. Geonode is a content management tool based on Dijango. It has the capabilities to control the roles, interaction, communication and upload directly to the server.

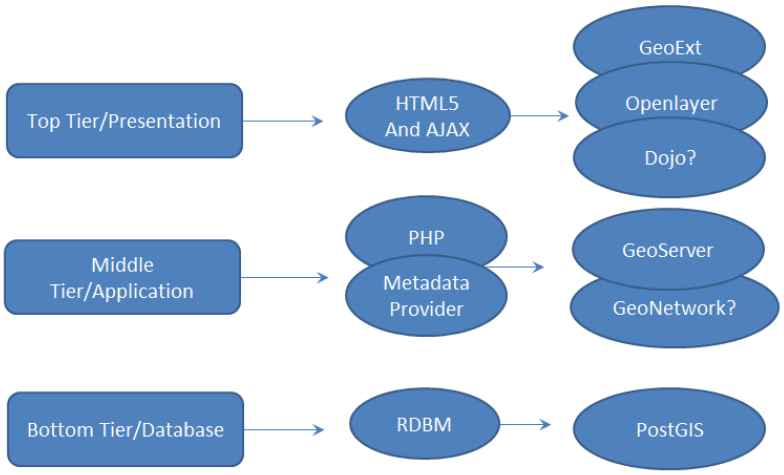

Figure 2: Three-Tier Architecture

4. Prototype

In this section, the background architecture of the ongoing prototype version of the proposed DSS is presented. As mentioned in the previous section, three-tier architecture has been applied with the support of Boundless architecture and its client side SDK application environment using gxp components and data utility classes, which extend map related functionality to the equivalent classes in Ext and they are configured to work with OpenLayers or GeoExt. It provides the powerful ability to create own customized plugins and widgets necessary for the application development. A connection to the PostGIS database is done by PHP script in order to communicate data from database to the client side JavaScript libraries such as ExtJs and Geo-Ext. via JSON format.

An ongoing prototype version using Boundless can be seen in Figure 3, where the users can access to the system, view the different user interfaces and interact with different functionality according to the access roles as defined in the database. The different modules have been developed as separate plugins (classes under Tool.js) in the application (app.js).Another alternative could be to use GeoNode (based on Django) or other online content management systems to deal more easily with user administration interface such as defining different roles for different users, synchronization with the user in Geoserver, adaption to the Geoserver layers and internationalization.

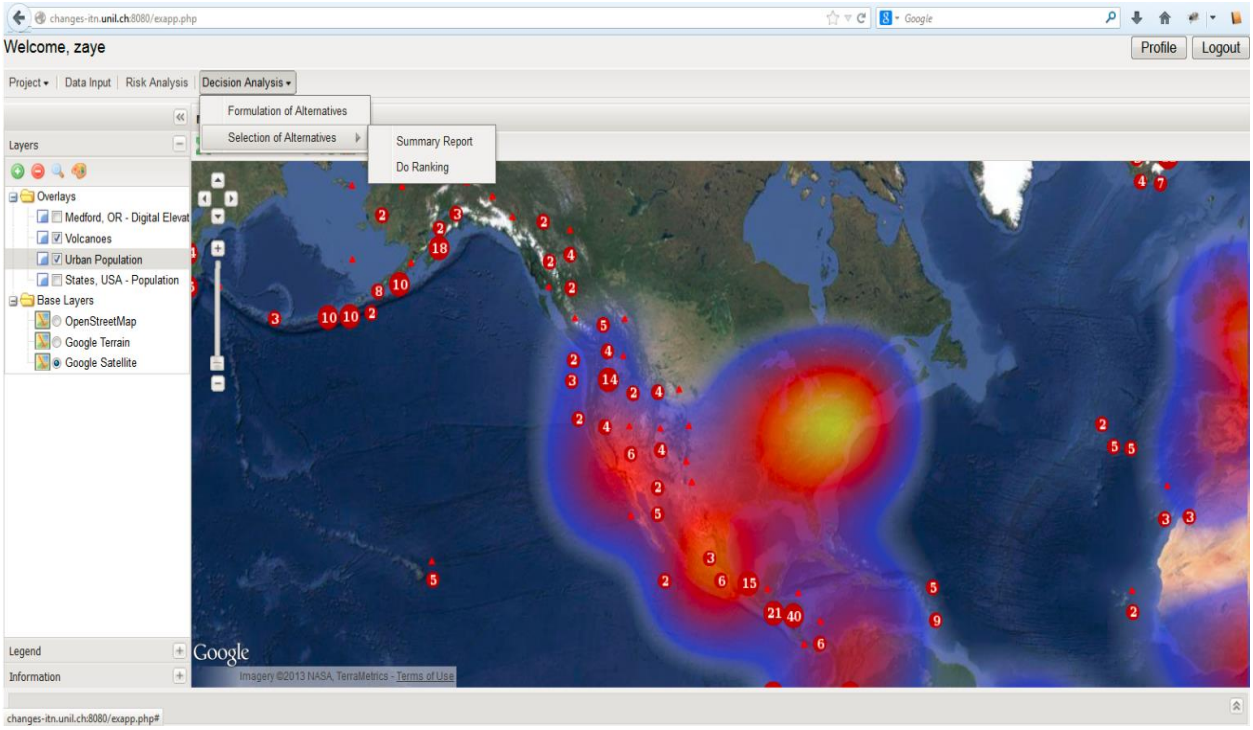

Figure3: Simple Prototype for SDSS by OpenGeo architecture

5. Conclusion and further releases

This paper presents the modularity of our SDSS system and how we can utilize the available Open-source web-based platform to deploy the Web-based SDSS for risk reduction on natural hazards. The outcome is to show the availability of Boundless architecture and how it can be applicable as SDSS architecture. The system is still under development and needs to be implemented in different case study areas of the project. There are many challenges remaining for this study in terms of: Availability of spatial data, standards and policies; Data quality which has an significant role in decision making; Model integration and linking them to other components; User managements and involving the users in SDSS for different visualization and analytical approach and the last but not least guiding the user through the different user interface and ease of use.

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