Master Thesis Gina CAMPUZANO

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Development of a GIS web application as a tool for learning of environmental protection
-Comparison between MapServer and GeoServer constructing a tool for not expert users-

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Abstract

Once again Geographic Information Systems (GIS) and spatial data management are being used to facilitate analysis of information and recognize the trend of behavior of different variables over the surface, being not the exception results of environmental experiments.

This thesis demonstrates the methodology for development of a GIS solution which reveals GIS as very important tool to contribute for science research. This GIS web application shows on the map results of energy saving procedures as environmental experiment done by kids in different places. These kids are students who participate in a project called Klimakids and they have before contributed with other kind of learning practices regarding to options to conserve the Earth. Klimakids is a project leaded by IfaS institute applying important learning methodologies as “Visible Learning” and “Feedback Culture” being GIS tool a good idea to implement more about these education methodologies.

Looking the best option to construct a GIS web application for not expert users, this thesis explains technical developing procedures making comparison between MapServer and GeoServer as main open source platforms for developing GIS on the web.

INTRODUCTION

Global warming and other environmental effects are challenges which may involve a big problem for the humanity. Germany being one of the leading nations in the area of environmental technology has worked about important projects and programs to control and reduce negative consequences on environment; therefore the environmental education is not an exception as a very important issue to control negative impacts for the use of natural resources. Environmental education starts from childhood. The aim of keeping environmental awareness and interest from children requires methodologies of education and learning processes which in this project are leaded by the Institute for Applied Education Management “IfaS” (Institut für angewandtes Schulmanagement) interested to develop a web GIS application to support a project called “Klimakids” being a joint project of the Foundation Energy & Climate Baden-Württemberg (Stiftung Energie & Klimaschutz Baden-Württemberg).

Klimakids project includes experiments which engage students to understand more about energy conservation, sustainability, mobility, climate change and renewable energy. IfaS leads seven schools with
more than 800 students who make experiments at home and places of expeditions during different periods of time. Experiments or practical actions are procedures to take measures like CO2 emissions, energy consume and its, water consume between others; besides outside of schools other experiments to verify the current condition of some places.

IfaS work focuses on education methodologies as “Visible Learning” and “Feedback Culture”. GIS answers encourage the application of these methodologies and motivate students to be connected with environment topics after to get clearer answers from spatial queries and comparisons of figures through the time. This is one fundamental reason why IfaS wants to construct a GIS web application following some parameters to keep a real interest of Klimakids students, their teachers and families, making to grow the engage of environmental protection and reflect what this means for the Earth “numerically” during next years. Such interest to continue the “Stiftung Energie & Klimaschutz Baden-Württemberg” effort, focused on issues related of energy supply and energy use in the context of climate change and their consequences.

This thesis project will deal the construction of a GIS application where the information and data acquisition must follow some requirements allowing an optimal geographic representation; therefore the project development will assist IfaS to manage procedures of thematic data acquisition from Klimakids students.

IfaS team was showing on its web page a map with seven project schools and some additional information; however this digital map didn’t satisfy IfaS team because it didn’t make a significant difference with respect to show the information just by words or figures.

Design of Spatial Database, queries and interface of GIS web application define initial parameters to represent geographic data of Klimakids project. The places of experiments are spatial objects to represent geographically the results of thematic data collection. Developing of GIS queries is the way to distribute the information keeping the integration of the full project results and data. GIS web application of Klimakids project returns a geographic web tool to be employed by not expert GIS users, focused on design and interface which will be managed by kids.

**OBJECTIVES**

First objective is development of Klimakids GIS web application with the best technology. Following the purpose for developing a very friendly GIS web application for kids, one of the targets of this master thesis is a period of researching to analyze, compare and demonstrate the best Open Source GIS programming option as well taking into account the aim of employ the geographic tool for visible learning and environmental protection. There are two main options of Open Source platform for geographic data and web mapping applications: MapServer and GeoServer. For both exist comparisons which show advantages and disadvantages regarding to technical performing like source of code, database connections, WMS WFS, servers, number of different workloads for vector and raster information. Nevertheless the focus of GIS web application for Klimakids project requests the assessment of other important features to develop queries which represent an impact for the attention of kids and not GIS expert users. Therefore interface development plays a vital role. Options of development for friendly queries, design and display are some key features of comparison between MapServer and GeoServer for Klimakids project.

Second objective is the application of GIS for Klimakids as a project for environmental protection and climate change issues.
Third objective is to demonstrate that GIS encourages important learning methodologies as “Visible Learning”; due to facilities that students have to recognize own results and feel engagement because they know that their procedure of learning contributes to the Earth.

METHODOLOGY

1.1. Analysis, Organization and Data Collection

During this stage it was done the analysis to assess which kinds of experiments are feasible to represent as spatial information; according to reliability of the measurements, relation to environmental impact, contemplation of new attributes and organization for collection of data. This job was done with constant support from IfaS team, due to some vital factors when it’s being working with kids, besides different procedures to construct documentation for people who participate in the project, like directives of each school, teachers, parents and students.

Klimakids project has leaded different kind of experiments basically done with Klimakiste\(^1\) instruments. According to project proposal, one requirement for this stage was related with meetings between IfaS team and me, choosing the experiment to implement and then construct document formulation to participants of data collection. During these meetings were covered subjects as current situation of Klimakiste, advantages and disadvantages, and examination of different devices and simulation of results before to put them into action.

Due to amount of Klimakiste instruments related with time of GIS Klimakids web application development and organization disadvantages when kids are not working at the same time the same activities; IfaS team purposed the option of saving energy directly with the power meter which each kid or student has at home.

At home students and family take data during periods of usual energy consume and then periods where the student and family are trying to save energy. Data collection of each consuming period must be taken from power meter device which each of us has at home. As can be noted, this is a work with participation even from Klimakids parents and family. That means a great effort from them and their participation even twice during two different times of year, besides IfaS team effort to construct easy and understandable documents for directives, teachers, parents and students.

After of measurements, students give worksheet to teacher and then are sent to IfaS office. It is made the fingering process to collect information within an excel file proceeding to the organization of data within a designed spatial database.

1.2. Model-View-Controller structure and Data Model

Klimakids GIS web application is developed under a software pattern knew as Model-View-Controller. This is a common pattern for developing of software which divides the code according with the main parts to construct any computer program; these parts are generally based on data (information), interface and commands (functions); these are model, view and controller respectively. This structure represents an

\(^1\) Klimakids box or klimakiste is a kind of toolbox which contains different equipments and instruments for environmental measurements and monitoring.
advantage to focus segments of software and make modifications without affect other parts. GIS web application is making comparison between MapServer and GeoServer which represents the “Controller” part, therefore “Model” and “View” could be the same for both developments.

Model-View-Controller pattern makes the structure of the program divided by model or structure of data, view or interface and controller or commands to define functions.

MODEL: Data storage according with Entity-relationship model which involves every edition of data into the same environment, for Klimakids GIS web application the model is within PostgreSQL with its respective PostGIS extension. After analysis of data collection are defined variables which make up the system; then it is designed the spatial database to store the information, besides creation of flow charts according with functions and basic structure “input/output” to identify queries of GIS web application.

VIEW: Interface and its design are done by a kind of programming language, which is separated from commands development or functions. To Klimakids GIS web application the view segment is constructed through HTML and CSS.

CONTROLLER: It is the programming which makes reaction to the client requests; this programming area is based on PHP for MapServer and JavaScript for GeoServer.

![Model-View-Controller scheme](image)

**Figure 1. Model-View-Controller scheme**

1.3. Georeferencing and geometry in PostGIS

Schools and Students must be georeferenced to create them as spatial objects or entities. Coordinates of schools is known and georeferencing can be done using OpenJUMP\(^2\) as open source software to construct Geographic Information Systems GIS. This is an option to make edition of shapefiles without requirement to buy software or license. Stuttgart University has ArcGIS being the main software for edition of shapefiles in Aerospace Engineering and Geodesy faculty, therefore during georeferencing procedure of this project it is used ArcGIS.

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\(^2\) *What is openjump?* Openjump is an open source Geographic Information System (GIS) written in the java programming language. It is developed and maintained by group of volunteers from around the globe* (OpenJUMP, 2011)
Data is stored within a spatial database constructed through PostgreSQL/PostGIS. Until this step there are implemented: schools shapefile, student shapefile and the experiment table. These two shapefiles (.shp) must be transformed as .sql file to be recognized by PostgreSQL. The procedure is done through a PostGIS command. This command has a direct connection of new PostgreSQL/PostGIS versions and it is possible to find it by the path where PostgreSQL is installed.

1.4. Basic GIS web application development under MapServer and GeoServer

After constructing MODEL or spatial database structure, it starts a period of documentation, analysis and proofs for developing a GIS web application. Therefore it is possible recognize kind of parameters which affect the GIS web application performance according with Klimakids priorities. Figure 2 shows general structure applied for both GIS web applications according with each open source environment server. During this stage of the project it is developed a basicGIS web application under MapServer and another under GeoServer, each one connected with MODEL, making also analysis of VIEW as interface structure, and if it is possible to improve performance due to MODEL or VIEW.

![Figure 2. structure used to construct a GIS web application under MapServer and GeoServer](image)

1.5. Klimakids GIS web application development under GeoServer

After following a development methodology of basic Klimakids GIS application under MapServer and GeoServer, it was decided the application must be constructed under GeoServer. First three steps “Analysis, Organization and Data Collection”, “Model-View-Controller structure and Data Model” and “Georeferencing and geometry for PostGIS” are applied for the final GIS application development in the same way.

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3 “Basic” makes reference to a GIS tool with common geographic control panel (zoom in, zoom out, pan, extend, layers) and one or two thematic queries. Final Klimakids GIS web application contains some more tools and popups.
Klimakids GIS web application development is explained under Model-View-Controller pattern. “Basic GIS web application development under MapServer and GeoServer” explains in general terms how is constructed the GIS web application under these two web mapping servers.

**Queries and Flow charts “input/output”**

Input is a kind of data which user wants to visualize geographically. This can be through a button of multiple choices, or a blank for filling a value. Output is a point or group of points over the map classified through attributes according with the Input.

<table>
<thead>
<tr>
<th>Description</th>
<th>Kind of Button</th>
<th>Input options by selection</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Query highlighting School</td>
<td>Multiple selection (HTML command: “Select Name”)</td>
<td>Seven schools which participate in klimakids project</td>
<td>Highlighting selected point and making zoom on it.</td>
</tr>
<tr>
<td>Query highlighting Klimakid</td>
<td>Blank space to be filled (HTML command: “Input Name”)</td>
<td>-</td>
<td>Highlighting queried point.</td>
</tr>
<tr>
<td>Query of energy saved</td>
<td>Multiple selection (HTML command: “Select Name”)</td>
<td>Energy saved during the night Energy saved during the day Energy saved during night and day Energy saved during two stages</td>
<td>Showing group of points which correspond to the input of selected group. Scaling values classified by colors and size.</td>
</tr>
<tr>
<td>Query of more results for comparison</td>
<td>Multiple selection (HTML command: “Select Name”)</td>
<td>Who saved during night and day Who saved more during the night Who saved more during the day Who saved during two stages Who participated for both stages</td>
<td>Highlighting points which correspond to the selected input group.</td>
</tr>
</tbody>
</table>

Table 1. Description of Buttons for Klimakids GIS web application
Figure 4. Flow charts for Buttons. Kind of HTML Buttons: “Select Name” and “Input Name” respectively.

Figure 4. Query of “energy saved” activated with different selection options.
Besides of panel of geographic controls and queries are programmed popups to know specific information about each school and student who participated in Klimakids for energy saving, and confirm data. This information contains:

For students: the Klimakid Code, class or course of student, if the student participated more than once and how much energy he/she saved during both stages.

For schools: city or town of school, number of students who participated in Energy Saving Experiment, amount of total of energy saved from group of students who participated, two top students who saved more energy.

![Figure 5. How it looks a selected student popup and selected school popup](image)

About the legend, a common legend maybe is not clear for kids and looking for an understandable tool it is not practical a traditional legend. Klimakids GIS web application has the option to display the meaning of symbols. It is possible to look on links panel a basic connotation and then click on the option to display detailed information. This explanation is deeper and about the symbols equivalence with respect to kWh.

**CONCLUSIONS**

*The same development target under MapServer and GeoServer*

This project was set out to construct a GIS tool for not expert users. The process to build this application on different platforms was very useful hence it was possible to compare directly two main open source alternatives to construct a GIS application, demonstrating that for Klimakids target the best option is GeoServer. Based on theory could seem MapServer better than GeoServer; nevertheless after conclude with basic development under these both platforms it were discovered some issues which affect the user interaction. Control panel: Even following main MapServer and GeoServer web pages, important comparison forums and documentation, there is not many information about the control panel structure under MapServer and important disadvantages about it. Time performance: It was known that due to CGI MapServer could be slower than GeoServer, this was the second disadvantage proved as significantly slower to be employed by not expert users.
There are new options as FastCGI which could improve MapServer performance. About MapServer interface and user interaction, it would be an option to construct a GIS web application with JavaScript and construct the map as .map file; taking into account that .map doesn’t enclose important advantages which PHP MapScript has, as such possibility of creation of complex geospatial functions. It is worthwhile researching of possible development options as:

- MapScript on Python or SWING environments.
- Combining JavaScript and .map file to assess MapServer performance and options of interface and geospatial functions as queries that JavaScript (OpenLayers) can support.
- Both options above if the development focus is different to Klimakids GIS web application. For example if those are better to raster processing or spatial queries like buffers or distances.

It was possible programming with MapScript a query option where the input is any specific data (instead of multiple selection) which loads or highlights the object on the cover. This kind of query is very important to GIS development, due to easier accessibility of any spatial object over the surface. During the development period for this project it was not possible to construct this kind of query under JavaScript, and I’m not sure if this is achievable; but it didn’t imply an obstacle to achieve the Klimakids GIS web application target.

**Model-View-Controller as a very good option of GIS development**

Klimakids GIS web application was done under Model-View-Controller pattern that facilitated procedures of construction, analysis and system updating. Besides, it was proved that if VIEW and MODEL structures are not well designed, even GeoServer could be not very useful for Klimakids project and difficult to manipulate for not expert users. Design and style play an important role to map container as well as to general design of commands and tools. Undoubtedly it was necessary to apply cartographic rules as amount of colors and sizes of points being part of CONTROLLER; nevertheless visual structure, kind of buttons and distribution of functions depends of HTML and CSS under MapServer and GeoServer, therefore the efficiency of any web GIS development or geospatial application depends of CONTROLLER (MapScript or JavaScript) as well as VIEW (HTML and CSS).

**GIS as a tool of Visible Learning**

Klimakids GIS web application allows recognizing better the contribution of environmental protection and climate change issues. This information under the application becomes something more “perceptive” and it is not related to specific statistics; nevertheless there are libraries to develop and show specific and general statistics, which could be also an option of researching or a GIS application improvement. Perceptive because any user can recognize easily trends and proportions of thematic data behavior over the surface, being more significant if the geographic representation is dynamic. This was the target for kids as main users. Besides it contains popups of data by student and school, showing some real figures obtained after of Energy Saving Experiment.

It is still in process of analysis the issue of Visible Learning and reactions of students. This would assess more the assertiveness of VIEW. Furthermore MODEL and CONTROLLER already fulfill technical parameters and are related with the assertiveness of GIS application as idea of learning. The application must be a tool which makes the kids as users to realize easier their contribution, feeling engagement when they recognize they make part of a dynamic spatial system; this brings the awareness about climate protection.
Future work

There are some ideas to continue this awareness project of climate protection. About the application it is possible to improve some interface aspects according with conclusions from surveys answered by students and if they felt comfortable using the application. Besides it will be analyzed if the application is really working as a tool for Visible Learning.

IfaS could promote Energy Saving Experiment to have participation of more schools. If the participation increases, IfaS team has interest to develop more about the application having the option to collect the information directly from web site being the users as students, parents, and teachers who introduce within the system experiment data by themselves. This would be another process of MODEL development where the spatial database is updated through participation of each user, besides the control of reliable data.

REFERENCES


http://openlayers.org/dev/examples/