TOWARDS A WEB-BASED GIS FOR TEACHING GEO-INFORMATICS AT UNDER-GRADUATE LEVEL IN DEVELOPING COUNTRIES: A CASE STUDY OF IRAN

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ABSTRACT:

In developing countries, the number of experts and students in geo-informatics domain are very limited compared to experts and students of sciences that could benefit from geo-informatics. In this research, we study the possibility of providing an online education system for teaching geo-informatics at under-graduate level. The hypothesis is that in developing countries, such as Iran, a web-based geo-education system can greatly improve the quantity and quality of knowledge of students in undergraduate level, which is an important step that has to be made in regard of the famous "Geo for all" motto. As a technology for conducting natural and social studies, geo-informatics offers new ways of viewing, representing and analysing information for transformative learning and teaching. Therefore, we design and present a conceptual framework of an education system and elaborate its components as well as the free and open source services and software packages that could be used in this framework for a specific case study: the Web GIS course. The goal of the proposed framework is to develop experimental GI-services in a service-oriented platform for education purposes. Finally, the paper ends with concluding remarks and some tips for future research direction.

1. INTRODUCTION

Nowadays, the importance of geo-informatics technology is well-known in almost all natural and social science disciplines and their branches. On the one hand, as a tool, GIS can provide the framework and means of spatial data collection, manipulation and visualization. On the other hand, as a science, GIS provides the basic concepts as well as methods for analysing and interpreting spatial data in various application domains. In developing countries, the number of experts and students in geo-informatics domain (including Geospatial Information System/Science, Remote Sensing, Photogrammetry, and Digital Cartography) are very limited compared to experts and students of sciences that could benefit from geo-informatics. As an example, In Iran only a few universities among hundreds provide facilities for students to study geo-informatics technology. Not to forget that almost all of these universities are located in the capital of Iran, Tehran. For entering these programmes students need to pass an entrance exam, which makes it even more difficult to study geo-informatics in Iran, since the number of total accepted students is very limited.

Apart from universities, there are only few programs offered by organizations and/or individuals and based on the results of a conducted survey the quality of materials and courses offered in this case are very low due to lack of professional lecturers in the domain as well as lack of resources (both software and hardware) for conducting the courses. Therefore, the goal of our research is to study the possibility of providing an online education system for teaching geo-informatics at under-graduate level. The hypothesis is that, in developing countries such as Iran (and also developed countries) a web-based geo-education system can greatly improve the quantity and quality of knowledge of students in undergraduate level, which is an important step that has to be made in regard of the famous "Geo for all" motto. As a technology for conducting natural and social studies, GIS offers new ways of viewing, representing and analysing information for transformative learning and teaching.

For this purpose, we started by reviewing the available literature in order to benefit from the experiences of similar projects. After providing the results of literature review and discussing the advantages and disadvantages of other works, we present the system architecture of a small Spatial Data Infrastructure (SDI) for teaching Geo-informatics courses. In this paper we introduce the open-source services that are available in this light-weight SDI, as well as the technologies and open-source softwares that can be used for the purpose of teaching. This is of great importance in Iran, due to lack of sufficient budgets for buying licences of commercial GIS products. Finally, we present the conceptual framework of the education system and elaborated its components as well as the free and open source services and software packages that could be used in this framework for a specific case study: that is the Web GIS course. The proposed framework is based on ZOO, and the goal is to develop experimental GI-services in a service-oriented platform.

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The structure of the paper is as follow. In the next section we introduce the related works that has been done regarding this topic and discuss their characteristic and benefits that could be used in our project. In section 3, the current situation and problems in Iran are reviewed and the requirements of developing the education system are discussed. Section 4 presents our methodology and the conceptual framework as well as the details about the selected courses in our project. Later, in section 5 we take the Web GIS course as a case study and elaborate more on the architecture of the system, based on the proposed framework. Finally, the paper ends with concluding remarks and some tips for future research directions.

2. RELATED WORK

In a research study, an experimental "GIS in Education" course for pre- and in-service teachers was introduced at North Carolina State University for social studies (Alibrandi & Palmer-Moloney, 2001). Participants experienced a complex technology and overcame barriers as they collaborated with university faculty to co-construct the course. The students chose final projects that applied GIS to analyze social problems spanning scales of local community history to international migration patterns. In another program, components of GIS were added to an existing methods course for students pursuing secondary social studies certification through the education program at Hartwick College. The hypothesis of these projects were that as a technology for conducting social studies, GIS offers new ways of viewing, representing and analysing information for transformative learning and teaching. The authors present models that which offer ideas for changing the role of technology use in social studies education (Alibrandi,1997). We strongly believe that analysing the presented models and using their experience can be beneficial for our project goal as well.

In another research study, as an initial assessment (Steiniger & Hunter, 2010) have evaluated and discussed the use of free and open source software's for teaching GIScience for geography and environmental sciences (under-graduate levels) at University of Zurich and University of Calgary. Their analysis was based upon three courses namely: Introduction to GIS, Advanced GIS and GIS Web Mapping project course. Several items of requirements were considered such as the course setting (e.g. infrastructure), course objectives, course content with respect to lecture and tutorial topics. In order to determine which software qualifies for teaching these courses the authors evaluated several free GIS software packages with respect to their functionality.

For the "*Introduction to GIS*" and *"Advanced GIS"* courses desktop GIS software was used, whereas the "*Web Mapping GIS group project"* required several types of software to build a web GIS system. The functional assessment for desktop GIS also included the proprietary software ArcGIS and was generally used for all GIS exercises. Based on a comparison between various GIS software packages (Table 1), (Steiniger & Hunter, 2010) discuss the strengths and weaknesses of each package and conclude that "free software has achieved a level of maturity that enables it to replace proprietary desktop GIS software when teaching *Introduction to GIS* and *Advanced GIS* level courses". The software projects that have reviewed appear to be stable and reliable; however for other software projects "one should consider the maturity of the project before adoption" (Steiniger & Hunter, 2010).

With respect to course projects that focus on web GIS development, the authors find no strong proprietary alternatives to using free software. They conclude that free web GIS solutions are generally more agile in their ability to adopt new web technologies and standards. The authors also discuss that while working on a web GIS development project, an instructor who uses open source software would be able to extend projects from a single semester to multiple semesters where the whole project could be built part by part in a modular-based way. This approach enables students to work as part of a larger body rather than as solitary implementers of one project. This would teach students about the interdependence of project-based work and how their modular blocks of works could fit within larger frameworks (Faber, 2002).

function	Course Level	ArcGIS	GRASS	QGIS	OpenJUMP	function	Course Level	ArcGIS	GRASS	QGIS	OpenJUMP
Raster/vector data	I	•	•	•	•	Carto. Projections	I	•	•	•	p
Create a map	I	•	•	•	P	Vector-to-raster	I	•	•	G	S
Query attributes	I	•	•	•	•	Raster resampling	II	o	•	G	S
Query distance	I	•	•	•	•	Reclassify	I	o	•	G	S
Query DE-9IM	I	•			•	Geom.-type change	I	o	•	•	•
Creating geom.	I	•	•	•	•	Geom. Simplify	I	o	•	•	•
Edit attributes	I	•	•	•	•	Landscape indices	I	p	•		S
Table/txt joins	I	•	•	•	•	Thiessen polygons	I	o	•	G	•
Basic statistics	I	•	•	•	p	Slope	I	P	•	G	S
Thematic maps	I	•	•	•	p	Contouring	I	P	•	G	S
Polygon overlay	I	•	•	G	•	Curvature	II	P	•	G	S
Zonal statistics	I	o	•	G	•	Flow direction	II	P	•	G	S
Map algebra	I	o	•	G	S	Flow accumulation	II	P	•	G	S
Multi-Criteria-Eval	I	o	P		S	Watershed	II	P	•	G	S
Sliver removal	II	o	•	G		Compound indices	II		•	G	S
Geom. Union	II	•	•	•	•	Viewshed	II	P	•	G	S
Geom. QA/cleaning	II	•	•	•	•	Hillshade	II	P	•	G	S
I:IDW	I	o	•	•	S	Profile graph	II	P	•		S
I:Spline	II	o	•	G		Extract raster vals	II	P	•	G	S
I:Contours to DEM	II	o	•	G		Fuzzy sets	II	o[2]	R		S
I:Kriging	II	o	R		S	Change matrix	II		•	G	
Kernel Density	I	o	R		S	Spatial indexing	II		•	•	•
Georeferencing	II	•	•	•	S	SQL	II	•	•	•	•
Metadata editing[1]	II	•				Scripting/Modeller	II	•	•	•	•

• functionality provided, o functionality provided with ArcGIS ArcInfo, but not with ArcView, P: separate plugin/extension, R: GRASS with R, G: QGIS with GRASS Toolbox, S: OpenJUMP with Sextante Toolbox, [1]a free metadata CatMDEdit exists, [2]Fuzzy overlay will be included in ArcGIS 10

Table 1. Software functionality evaluation for teaching Introduction to GIS (I) & Advanced GIS (II), adopted from (Steiniger & Hunter, 2010)

In another more recent study, (Köbben, De By, Foerster, Huisman, Lemmens, & Morales, 2010) introduce the concept of SDI^{light} approach in teaching Geo-informatics at University of Twente. Within the SDI^{light} approach, the authors have adopted "a reference system stack using open source components, where any system realisation can be seen as a conscientious pick from that reference stack" (Köbben, De By, Foerster, Huisman, Lemmens, & Morales, 2010). This approach provides students a platform for simple, low–cost, yet powerful and efficient means of sharing data amongst various distributed nodes. To achieve this, the authors have used open standards whenever available, open source solutions where possible and commercial software where necessary. In the article, the authors discuss the methodology of developing the approach and its usefulness in teaching, research as well as projects.

Furthermore, they discuss the setup of the Geo-informatics Master course, in a modular based way, consisting of several modules each of which covering certain professional skill to be taught to students (e.g. spatial data modelling, geo-visualization, etc.). This is done through performing a case study application building and programming (e.g. a primary school planning system). The main objective of this part as defined by the authors is to teach students how to apply their skills in a real project. The students are required to build a

coherent system for spatial data acquisition, storage, access, analysis and dissemination based on available standards.
It is strongly believed that the results of the later study could be beneficial for our project in order to develop a web-based GIS for teaching geo-informatics at under-graduate level. In the next section we define the current situation in Iran in order to discuss the current problems and later in section 4 we show how the concept of SDI^{light} is adopted to build our conceptual framework.

3. CURRENT SITUATION IN IRAN AND SYSTEM REQUIREMENTS

In developing countries, the number of experts and students in Geo-informatics domain are very limited compared to experts and students of sciences that could benefit from Geo-informatics. In Iran only a few universities among hundreds provide facilities for students to study Geo-informatics technology. Apart from universities, there are only few programs offered by organizations and/or individuals and based on the results of a conducted survey the quality of materials and courses offered in this case are very low due to lack of professional lecturers in the domain as well as lack of resources (both software and hardware) for conducting the courses. Therefore, in the initial step taken towards the aim of our research study, we have decided to use free and open source software packages for teaching geo-informatics courses.

There is sometimes confusion about what 'free' software actually means. The term 'free' refers not only to free-of-cost, but also to freedoms granted to the users by the software license. These freedoms include the right to (i) run the program for any purpose (e.g. educational or business use), (ii) study and understand the program, (iii) freely copy and distribute the program, (iv) modify the program, and distribute the modified version. Hence, the opposite of *free* software is not *commercial* software but *proprietary* software, which stresses ownership.

Due the all above-mentioned rights, using free software packages is of main importance in our project due to lack of sufficient budgets and resources in Iran for buying commercial softwares. Besides the cost advantages of free and open source packages, it is important to make sure if there are enough such packages to be used for developing and running geo-informatics courses. Table 2 shows a list of up-to-date free (and in some cases open source) packages selected as best candidates to be used for our running project.

Name	Description
Postgresql (and PostGIS)	A Database and its spatial extension
ILWIS	An Integrated Land and Water Information System
Quantum GIS	A complete Geographical Information System
uDig	A GIS software program
Geoserver	An open-source server written in Java - allows users to share, process and edit geospatial data.
Mapserver	An open source development environment for building spatially enabled internet applications
MapFish	An open source web mapping development framework
OpenLayers	An open source AJAX library for accessing geographic data layers of all kinds
GeoTools	An open source GIS toolkit written in Java, using Open Geospatial Consortium specifications.
gvSIG	A geographic information system as a desktop application
Geomajas	An open source GIS framework used for web mapping
R	A free software environment for statistical computing and graphics.

Table 2. List of selected free and open source software packages for the education system

4. METHODOLOGY AND CONCEPTUAL FRAMEWORK

In the first step of our methodology, we asked several students, experts and professors in various domains about their level of understating of geo-informatics as well as the need of this technology in their projects and studies through a questionnaire. The result of this questionnaire leaded to selecting four main courses to be available that would cover the very first needs of students in domains such as Environmental Engineering and Natural Resource Management, Urban Planning, Civil Engineering, as well as Computer Software Engineering and Information Technology. These disciplines have been chosen based on the popularity of the disciplines in Iran (targeting the majority) as well as the proven need of GIS technology for all of them. Based on the results of a conducted questionnaire, several basic courses were defined, namely: *Geo-Database Management Systems*, *Introduction to GIS*, *Introduction to Remote Sensing and Photogrammetry*, *Geo-statistics*, *Neo-Geography & Volunteered Geographic Information (VGI)*, and *Web-GIS*. It is believed that offering these courses would be a good start for the target students to learn and use geo-informatics in their own disciplines. In the next step a list of free and open source software packages/languages (Table 2) and services (Table 3) were selected through literature review in order to be used by our education system.

URL	Description
JSFIDDLE.NET	Online test and validation of HTML, CSS and JavaScript codes
JSLINT.COM	The JavaScript code quality online tool
GEOJSON.IO	Online validation tool for GeoJSON, TopoJSON, KML, CSV, GPX and OSM XML datasets
GEOJSONLINT.COM	Online validation tool for GeoJSON data through programmatic access
CHARTJS.ORG	Free and open source service for object-oriented graphs for designers and developers

Table 3. List of selected services for the education system

Furthermore, as a Learning Management System (LMS) we have decided to use OLAT (Online Learning and Training) (Fisler, & Schneider, 2008). OLAT is a free and open source LMS tailored to the needs of universities and higher education institutions. The development of OLAT is driven by the University of Zurich where it is extensively used. There are approximately 70,000 users and nearly 50 institutions in Switzerland using OLAT (with up to 5,000 courses and millions of resources), and the numbers keep on growing which shows the applicability and strength of this system in practice. OLAT

has several advantages for instance it is available in several languages and can provide diverse functionality for all your needs in web-based learning and training. The reason for choosing OLAT is that it is well proven to provide several basis functionalities such as the ability to (Fisler, & Schneider, 2008):

- author, manage and publish courses
- perform e-Assessments and questionnaires
- implement various forms of media for effective teaching
- provide an interactive and intuitive platform for stimulating learning
- create collaborative groups complete with tools such as forums, wikis and chat

In the third step we adopted the concept of SDI^{light} (Köbben, De By, Foerster, Huisman, Lemmens, & Morales, 2010) and designed the conceptual framework of our system based on four main building blocks (Figure 1) : (i) spatial database backend that stores the spatial data using the Open Geospatial Consortium (OGC) Simple Features specifications, OLAT, as well as other Web Processing Services (WPSs) that are aim to be integrated into the education system (explained in detail in section 5), (ii) a set of interoperable middleware web applications that are used in order to communicate with the database backend as well as users (human/services) (e.g. MapServer, GeoServer, etc.), (iii) thin browser-based clients for creating the User Interface (UI) such as HTML, Javascript, OpenLayers, and CSS, and (iv) thick clients used for data editing and performing spatial analysis (e.g. Quantum GIS).

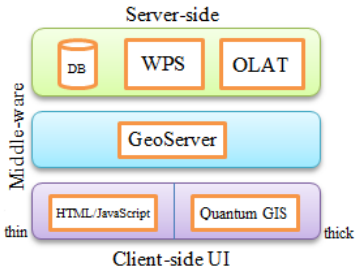

Figure 1. The conceptual framework

5. CASE STUDY: WEB-GIS COURSE

As a case study, in this paper we have selected the Web-GIS course to elaborate the applicability of our conceptual framework. It is also the most interesting case study, since a web-based GIS is used for teaching Web GIS course. Figure 2 shows the conceptual framework modified applied based on the ZOO project (ZOO project, 2014). Zoo is an open service for developing Web Processing Services (WPS) and it consists of three parts; (i): ZOO Kernel: A powerful server-side C kernel which makes it possible to manage and chain web services implemented in different programming languages, (ii): ZOO Services: various existing services in an open source library, and (iii): ZOO API: A server-side API able to call and chain the web services, which makes the development and chaining of processes easier. The main reason we are using the ZOO project is its capability to integration various processing services into one platform (service aggregation). Each service aims to give specific functionality to be used by for the Web GIS course. Zoo project takes the code of a specific service (written in almost any programming language) and turns it into a service integrated with other services (controlled by the ZOO API and ZOO Kernel). For example, the JavaScript code for Chart.js could be turned into a service providing graphical representations for the results of a certain spatial analysis task performed by the Web GIS.

More specifically, ZOO API can be used in order to develop GI-Services based on existing methods and techniques that aim to be used in the education courses. Each service can provide special functionalities for teaching/testing geospatial methods necessary in various courses. In our example, Chart.js WPS would be useful for generating graphical outputs (e.g. bar charts, pie charts, etc.) for courses such as Web GIS, geo-statistics, etc.

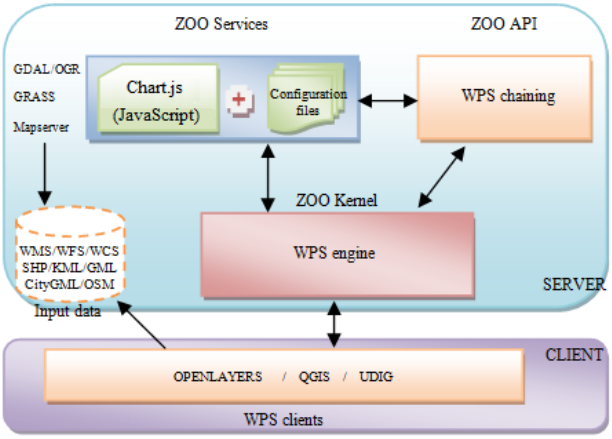

Figure 2. The Architecture of ZOO project for WebGIS platform including Chart.js as an example of aditional WPS (ZOO project, 2014)

6. CONCLUSION AND FUTURE WORK

Providing access to students of all disciplines to study and learn geo-informatics is of great importance in developing countries such as Iran. In this paper we studied the possibility of developing a web-based GIS education system for teaching geo-informatics courses. We asked the experts and professors as well as students via a questionnaire queries about the importance and need of geo-informatics technology in their domain of interest. The results of this questionnaire led us to some main geo-informatics courses that are necessary for some selected majors at under-graduate level. In the next step we presented the conceptual framework of the education system and elaborated its components as well as the free and open source services and software packages that could be used in this framework for a specific case study: that is the Web GIS course. The proposed framework is based on ZOO, and the goal is to develop experimental GI-services in a service-oriented platform.

For future work, we aim to consider implementing the Education system for the Web GIS course as a test bed, and try it in action by offering an online education course for teaching Web GIS to students in Iran. The gained experience from this test could be beneficial for improving the possible lacks and problems of the system. The final goal would be to complete the education system by adding the possibility of teaching other geo-informatics courses and improving the education system

based on the feedbacks received from professors and students whom interact and use it.

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