Servicing Environmental E-Learning (E^2-Learning): using Geographic Information and Remote Sensing Web Services to support E^2-Learning

Dimitris Kotzinos[1], Giorgos Konstantinou[1] and Nektarios Chrysoulakis[2]

Abstract

E-learning efforts, that use or support environmental information, have been around for quite some time now. In this work a framework of environmental web services is proposed, described and developed in order to support the creation of a virtual environmental lab, shared among different higher educational institutions. Several algorithms and data are implemented as case and feasibilty examples and presented in the paper. Also the corresponding clients that provide access to the web services have been implemented and can be used independently by each contributing institution in order to provide a customization mean. This work aims at complememting and work alongside with both in class teaching and e-learning systems.

1. Introduction

The last few years the e-learning community has gone into stringent efforts in order to support in class learning and training with computerized, more specifically web based, tools and services. These efforts tend to complement the instructor and not to replace him. With recent advances in Information Technology new tools and services are being developed in order to provide learners with access to algorithms and data that were not available before. Environmental education can greatly benefit from that, since it is heavily based on algorithms and the data they are using. Usually these algorithms and data are not available to everybody who aims at teaching a class at a university level, resulting to students with missing or at best only theoretical knowledge on specific subjects. This was due to the size of the required data, the inability to get these data or to get them in real or near real time and the inability of the instructor to find or code himself certain algorithms for the learners to use on their computers.

Environmental education may be supported with data derived from several sources (GLOBE, 2005), however, earth observation satellites that provide large geographic coverage and record the incoming radiation in various parts of the electromagnetic spectrum, may be a continuous source of accurate information on a repetitive basis, as well as historical information from archives of data. In recent years satellite remote sensing has increased its capabilities due to the improved spatial, spectral and radiometric resolution of the satellite sensors. Furthermore, new satellites that have been placed in orbit give the possibility for a considerable improvement in the images' temporal resolution. As a result, new measurements are now feasible in thematic areas of high environmental concern (Cartalis et al., 2000). Remote sensing has proved to be a valuable tool for environmental and earth sciences, yet its value can be extended to education as well. The use of remote sensing can enhance students' skillfulness in

[1] Department of Computer Science, University of Crete, P.O. Box 2208, 71110 Heraklio, Greece
email: kotzino@csd.uoc.gr, internet: http://www.csd.uoc.gr/, phone: +302810393532
2 Regional Analysis Division, Institute of Applied and Computational Mathematics, Foundation for Research and technology - Hellas, P.O. Box 1527, 71110 Heraklio, Greece
email:zedd2@iacm.forth.gr, internet: http://www.iacm.forth.gr, phone: +302810391762

environment - related subjects, as it allows them to study wide areas in detail with an interdisciplinary approach and begin to understand how different environmental features are related to one another. It offers thus, the opportunity to understand the relationship between the human and physical environment that is how people utilize the natural resources to satisfy their needs. Moreover, it has major advantages as a flexible vehicle for the learning process, since it provides attractive, familiar imagery and challenging mind-expanding processes that can stimulate students' interest and enhance their understanding of the Earth system processes. The comprehension of the algorithms and data used in remote sensing relies on an appreciation of the physical sciences. Understanding how sensors make use of the electromagnetic radiation requires an understanding of the electromagnetic spectrum itself and the way bodies generate electromagnetic radiation. The interpretation of the resulting images in turn, requires an understanding of the way radiation interacts with different materials. Therefore, remote sensing offers a uniquely powerful resource for teachers crossing a range of disciplines providing a good opportunity for cross-curriculum teaching (Barnett et al., 1995; Trend, 1995).

The work presented in this paper takes into account all the necessities derived from the environmental education experiences in higher education and acknowledges its special characteristics in terms of models, algorithms and data. It does not intent to be compared against other generic e-learnong efforts because it is not such. So efforts like the Shareable Content Object Reference Model (SCORM - http://www.adlnet.org/Scorm) and the Open Knowledge Initiative (OKI - http://web.mit.edu/oki) that are aiming at providing a complete reference system and object model so as other e-learning systems to be built on top or systems like ODESeW (http://www.esperonto.net/semanticportal/jsp/frames.jsp) (based on WebODE platform), OntoWeb (Jarrar et al., 2000) and OntoPortal (Carr et al., 2001) are semantic web portals that can support e-learning systems if the necessary semantics are provided are complementary and not competing to our work.

The proposed framework in this paper aims at the creation of a virtual lab that will support environmental e-learning, possibly among different universities. We have identified that a bottleneck in using e-learning during environmental related courses was the lack of the corresponding data and algorithms. We propose an open and expandable framework based on the use of web services (Saganich, 2001) in order to diassociate the data availability from their location, allow different plugable algorithms/components to be used for educational purposes (to facilitate for example comparison between different algorithms that perform the same task on the same data) and provide support and customization for different computing environments since different clients can be built on different computing environments but use the same web services. The proposed framework of GIS web services can be combined with existing e-learning systems that support web services, allowing for a greater integration in the educational efforts of our time.

In the next section the necessary algorithms and the corresponding data for the implemented web services will be introduced and explained. Section 3 shows what we have done to turn these components into web services, what the framework provides and what has been developed so far. It will also be discussed the availability of different clients and how this facilitates the use of the framework under any environment. Finally, section 4 will draw some conclusions and some pointers for future work.

2. Environmental Information in education: Algorithms and Data

New observing systems have greatly enlarged the amount of material essential to an undergraduate environmental education, including both the observing systems themselves and the environmental phenomena they detect (Wash et al. 1992; Byrd et al. 1994). Improvements in computers, image processing algorithms and data availability are expanding the possibilities for teaching techniques and classroom and laboratory activities, but with additional costs and difficulties to overcome as shown by Sato and Yokoyama (2001):

- It is difficult to analyze the imagery using conventional programming methods, since typical programming languages such as C may be versatile, but require a long time practice for students;
- commercial dedicated software, e.g., ERDAS Imagine, PCI Geomatics etc. have a considerable cost and they require long time to exercise as well;
- high spatial resolution satellite data have a considerable cost, whereas real-time low spatial resolution data require the operation of a satellite ground receiving station.

Information technology has become a powerful tool for environmental education, since it can provide a wealth of data for the students. The internet has been taken up as the latest educational initiative for E^2-Learning. The development of a virtual remote sensing environment enabling the application of image processing algorithms through a user-friendly interface, as well as the communication with a satellite receiving station through internet, may allow students to extract real-time environmental information from the station's data during the education activity. To achieve this goal, the Web Services technology was used in this study, as it provides the means for both: developing the user-friendly interface and communicating with the satellite ground receiving station in real-time. This method's strong points are that a) the computing environments is transparent to the students and b) the data being manipulated are presented to the students in a very direct and accessible manner.

As it has been already mentioned, remote sensing supports the description of the prevailing environmental conditions, as well as the state of the environment, with good spatial and temporal resolution. One of the most important parameters in environmental monitoring is the land cover and its seasonal and annual changes. In the case of low spatial resolution satellite imagery, that allows wide area monitoring, changes in land cover are directly related with changes in vegetation. The spatial distribution of vegetation and its seasonal and annual changes can be derived from low spatial resolution satellite data using vegetation indices such as the Normalized Difference Vegetation Index (NDVI). The algorithm producing the NDVI spatial distribution from AVHRR (Advanced Very High Resolution Radiometer) images onboard NOAA (National Oceanic and Atmospheric Administration) satellites, was chosen as a demonstration in this study, because it is a simple algorithm and rather easy to implement using only satellite data, since our focus is on the services of the framework. The NDVI is calculated for cloud free land areas taking into account the radiation received in AVHRR channels 1 (0.58 - 0.68 μm) and 2 (0.72 - 1.10 μm). The implementation of the NDVI algorithm and the visualization of the spatial distribution produced are performed by a Java-based in-house developed software. The various steps of these procedures have been described in detail in past studies (Chrysoulakis and Cartalis, 20002; Kotzinos and Chrysoulakis, 2004). NDVI is calculated by using sequences of AVHRR images, acquired in real-time in FORTH (Foundation for Research and Technology – Hellas) satellite image receiving station. The FORTH satellite receiving station, operational since 2002, has the advantage of real-time image acquisition. Image data from NOAA 12, 14, 15, 16, 17 and 18 satellites is received with a spatial resolution of 1.1km at nadir and five spectral channels in the visible, near infrared, short-wave infrared and thermal infrared regions of the electromagnetic spectrum (Chrysoulakis and Opie, 2004). The Web Services technology gave to this station the potential to be used as an operational tool for environmental education and especially for E^2-Learning activities.

Since AVHRR data may be used in various environmental applications such as weather analysis, cloud classification and tracking, environmental monitoring, land cover classification, sea and land surface temperature monitoring, energy budget studies, aerosol studies etc., it is obvious that remote sensing technology has the potential to support the requirements of E^2-Learning by providing both data and the analytical methods to retrieve environmental information in real-time. Therefore, the general objective of the application developed is to motivate students to acquire a wide variety of information about satellite image analysis and extend their understanding of the scientific relationships between different environmental components as well as to realize the interactions between different disciplines. In this

context, students can utilize this application to extract real-time information based on satellite data, to support their projects and presentations, develop their qualities and skills in the University community.

3. Environmental E-Learning through Web-Services

A framework of open and expandable GIS and Remote Sensing web services has been developed in order to be able to apply the NDVI algorithm to AVHRR images, acquired in real-time in FORTH satellite image receiving station (both of them described in Section 2). The NDVI algorithm was chosen for its simplicity and ease of use, along with its value for environmental education processes. We decided to separate the necessary actions to different web services to allow for better expandability and to facilitate easy substitution of the proposed services. More specifically:

- The web service *ImageSelect* which gives the ability to the client to retrieve the desired image after a seach in the satellite image database. This service returns the image's XML description to the client.
- The web service *ImageProcess_ndvi*, which applies the NDVI algorithm to a multi-channel satellite image, afterwards saves the produced image and its XML description on the server and returns the description to the client.
- The web service *ImageView*, which is responsible for displaying the produced image requiring the XML description of a resulted image as an argument and returns the URL of the display applet.

The proposed web services can be augmented with new ones, for example one web service that will compute cloud coverage from the same satellite images, or substituted, for example by another NDVI calculation algorithm. It is obvious that we can compare side by side and on the same data algorithms that perform the same tasks and all that are made available to end users through a client interface built specifically for their educational environment.

The framework was built in Java (although web services are by nature platform and language agnostic) and corresponding Java tools for web services support were used (TOMCAT, XERCES, AXIS – all from the Apache Foundation project found at http://www.apache.org) and SOAP (http://www.w3.org/TR/soap/) for message exchange among the different services and the clients using them. Due to space limitations readers are refered to (Kotzinos and Chrysoulakis, 2004) for more implementation details.

The final important piece, although not part of the framework, is the development of clients that are able to take advantage of the proposed web services and use them either through a web browser or as a desktop application. A variety of clients can be developed. Although we have already developed three of them just to show the ease and feasibility of such an action, one can built numerous clients depending on the users he is targeting. That way what the end user gets to work with can be fully customized and as mentioned earlier issues based on languages and educational cultures can be easily resolved. As part of our usability testing we have developed three clients:

- a web based client, that requires only a web browser to be used
- a desktop Java based client, which requires a Java Virtual Machine (JVM) on the Desktop, and
- a desktop C# client, which requires Microsoft .NET Framework in order to run.

That way we can demonstrate that any kind of platforms (Web, Linux, Unix, Windows) can be easily served by the framework, so the educational institution using it does not need to invest on any hardware (moreover since the processing power for the services will be provided by the hosting institution).

4. Conclusions and Future Work

In this work we have proposed and developed a framework based on environmental web services that can support environmental e-learning in higher education institutions. The framework provides the means for instructors and learners to use in or out of class algorithms and data as if they were locally available. The

framework allows for easy addition and substitution of services by others and for the development of clients that can be tailored to the needs of the specific users allowing for seamless integration in the existing learning process.

In the near future we intend to put the framework under real life testing by building a virtual lab shared among some of the Greek Universities. This will allow each university to contribute the available algorithms and data in the form of web services (either by deploying the existing ones or by developing new ones, which means augmenting the number and quality of the services offered) and all of them to form a virtual environmental lab, where all the available services will appear as being served locally. Moreover we would like to integrate the web services in existing e-learning environments in order to support actual e-learning besides the virtual lab environment.

Bibliography

Barnett, M., Kent, A. and M. Milton, 1995. Images of Earth – A teacher's guide to Remote Sensing in Geography at Key Stage 3 and GCSE. The Geographical Association.

Byrd, G., R. DeSouza, W. Fingerhut, and C. Murphy, 1994: Integrating technology into the meteorology classroom: A summary of the 1993 Northeast Regional Unidata Workshop. Bull. Amer. Meteor. Soc., 75, 1677-1683.

Carr, L., Kampa, S., and Miles-Board, T.: OntoPortal: Building Ontological Hypermedia with the OntoPortal Framework. MetaPortal Final Report 2001. The semantic portal is available at: http://www.ontoportal.org.uk

Cartalis, C., Feidas, H., Glezakou, M., Proedrou, M., and N. Chrysoulakis, 2000. Use of Earth Observation in support of Environmental Impact Assessments: Prospects and Trends. Environmental Science & Policy, 3, 287 - 294.

Chrysoulakis, N. and C. Opie, 2004. Using NOAA and FY imagery to track toxic plumes caused by the 2003 bombing of Baghdad. International Journal of Remote Sensing, 25, 5247 - 5254.

Chrysoulakis, N. and C. Cartalis, 2003: A new algorithm for the detection of plumes caused by industrial accidents, on the basis of NOAA/AVHRR imagery. International Journal of Remote Sensing, 24, 3353 – 3367.

Kotzinos, D. and N. Chrysoulakis, 2004. GIS Web Services and satellite imaging as a framework for environmental monitoring: the design and implementation of a vegetation indices calculation test case. In: Altan, M. O. (Editor), The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences: DVD-ROM of Proceedings of the XXth Congress of the International Society for Photogrammetry and Remote Sensing (ISPRS), Vol. XXXV, Part B.

GLOBE, 2005. The GLOBE Program. http://www.globe.gov

Jarrar, M., Majer, B., Meersman, R., Spyns, P., Studer, R., Sure, Y., and Volz, R.: OntoWeb Portal: Complete ontology and portal. In Proceedings of the 17th National Conference on Artificial Intelligence, Austin, USA, July 30-August 3, 2000, AAAI Press/MIT Press.

Saganich, Al. 2001. Java and Web Services Primer, http://www.onjava.com/lpt/a/1025

Sato, K. and R. Yokoyama, 2001. Teaching aid for Remote Sensing and map imagery analysis using EXCEL spreadsheet and VBA. 22nd Asian Conference on Remote Sensing. Centre for Remote Imaging, Sensing and Processing (CRISP); National University of Singapore; Singapore Institute of Surveyors and Valuers (SISV); Asian Association on Remote Sensing (AARS).

Trend, R., (Ed), 1995. Geography and Science, Forging Links at Key Stage 3, Geographical Association.

Wash, C. H., R. L. DeSouza, M. Ramamurthy, A. Andersen, G. Byrd, J. Justus, H. Edmon, and P. Samson, 1992: Teaching with interactive computer systems: A report on the Unidata/COMET/STORM Workshop on Synoptic/Mesoscale Instruction. Bull. Amer. Meteor. Soc., 73, 1440-1447.