

A WEB-BASED VIRTUAL LABORATORY FOR SATELLITE IMAGE PROCESSING AND ANALYSIS

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ABSTRACT:

With continuous increase in the utilization of satellite images in various engineering and science fields, it is imperative to equip students with additional educational aid in subject of satellite image processing and analysis. In this paper a web-based virtual laboratory, which is accessible via internet to anyone around the world with no cost or constraints, is presented. Features of the laboratory has been discussed in addition to details regarding system architecture and its implementation. Virtual laboratory is tested by students, whose responses are also presented in this paper. Future development of this laboratory is outlined in the end.

1. INTRODUCTION

Over the last few decades there has been an increase in utilization of satellite image data in areas such as Climatology, Urban area monitoring and development, Forestry, Agriculture, Defense, Geology and many more. There are many satellites belonging to different countries for earth observation and image datasets captured by these satellite sensors are abundant. However, it is felt that the potential of these remotely sensed image datasets has not been utilized to its full extent. It could be related to lack of qualified manpower to exploit potential of these image datasets. Apart from qualified and expert teaching faculty, well integrated educational content, demonstrations of theoretical concepts, compact software are needed for addressing this problem.

There are some commercially available software tools and packages, but they are economically not viable, if the only purpose to procure them is to teach and train. So this commercial aspect discourages teaching community from using these software packages as teaching aids in their classes. It is desirable to build a system or a software package that would be available free of cost and that which is easily accessible.

This paper describes an attempt to address these problems through development of a web-based virtual software laboratory that caters to hands-on sessions from anywhere around the world with limited theory, procedure and assessment components. Introductory knowledge of image processing and analysis is indispensable for geographers, environmentalists, urban developers, disaster management organizations and resource scientists. The subject of image processing involves understanding concepts of image manipulation and extraction of information from images.

2. STATE-OF-THE-ART

Lamar et al., (2005) defined virtual laboratory as a new technology, based on the internet, that has wide usage in a variety of technical fields because of its inherent ability to allow many users to participate simultaneously in instruction (education) or in the

collaborative study of common problem (real-world application). Also, Carnevali and Buttazzo (2003) described virtual laboratory as a computing system that allows to share the physical resources available in a laboratory with remote users connected on the internet. The web-based tutoring system presented in this paper fits the requirements for it to be considered as virtual laboratory because multiple users can access it through the internet and perform various experiments remotely. Sample data and required software for executing experiments are provided on the laboratory web-page.

Virtual laboratories for different engineering and science education have been reported in literature. Benetazzo et al.,(2000) describe a network of computer laboratories for familiarization and experimentation with instrumentation and measurement procedures. Also, the same paper stresses upon the necessity of providing hands-on approach to students for effective practical expertise. It also concludes that virtual environment is effective in cost reduction and student satisfaction. Magistris (2005) illustrates a virtual laboratory for a basic course in electro-magnetics. It also extends support for effectiveness of virtual laboratory in education. Cho et al.,(2003) implemented a Flash based multimedia tutoring system for biomedical engineering students. Woolf et al.,(1996) demonstrated multimedia tutors for intelligent manufacturing. Venkatachalam et al.,(2006) implemented a comprehensive Geographic Information System (GIS) tutor with subject content, animated demonstrations and case studies, self-assessment quiz, and a limited edition of Indian Institute of Technology Bombay (IIT Bombay) GRAM++ GIS software that runs on a desktop. Towards web enabled learning, there are examples of virtual laboratories that are based on controlling physical hardware using remote access provided to the student through internet Srivastava et al.,(2011). Ozturk (2011) describes a system for integrated circuit design using a simulator to provide experience based learning for the student. Goodwin et al.,(2011) developed virtual laboratories where they emulate physical systems through software and present an interface to the student to get access to various components of the systems. It is to be noted that virtual laboratories related to various engineering and science streams are developed at IIT Bombay. These include electrical engineering, electronics and com-

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munications, mechanical engineering, civil engineering, chemical engineering, biotechnology and biomedical engineering and physical sciences. Some of these laboratories enable one to control hardware remotely in addition to tasks such as simulation. Virtual laboratory presented in this paper can be accessed at <http://vlabs.iitb.ac.in/csre/siplabs/index.jsp>. To the best of the knowledge of the authors of this paper, there are no web based detailed learning systems for satellite image processing and analysis. This paper addresses this gap by describing a system developed by us at CSRE, IIT Bombay.

3. FEATURES OF VIRTUAL SATELLITE IMAGE PROCESSING AND ANALYSIS LABORATORY (VSIPAL)

To enhance the learning experience, the following features are included in web-based VSIPAL. The facade of VSIPAL home page is shown in Fig. 1. Its structure enables a student to better understand various topics in the related subject.

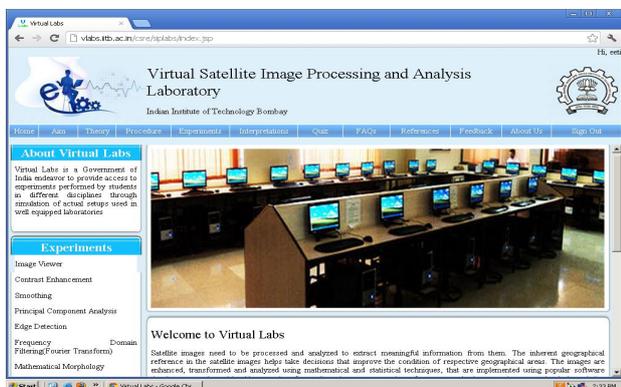


Figure 1. VSIPAL home page

3.1 Theory

This component consists of contents with respect to theoretical principles of various image processing and analysis and related mathematical details. In addition, video lectures are also embedded within this component (see Fig. 2 and 3). It is expected student/user would be benefited more by providing video lectures apart from brief discussion of a concept. *Theory* component aims to familiarize a student with various image processing and analysis concepts. Since the idea behind the concept is discussed in brief it would help student to get an overview of a concept. On the VSIPAL website reference books are also recommend for further studies.

3.2 Experiments

This component enables students to have hands-on experience with various concepts. This component is a software that contains 17 experiments. The related interface is interactive in the sense user/student provides various input parameters for executing an experiment. The result will be displayed either in a new pop-up window or on the same window. It is to be noted that only a registered user can execute experiments. VSIPAL is a free web-based software package and hence there are no charges of any kind to get access to this system. View of interface after executing one of the experiments is shown in Fig. 4. This *Experiments* component plays a major role in virtual laboratory.

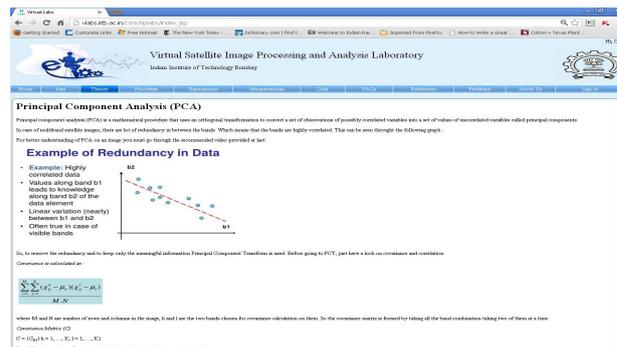


Figure 2. Theory about principal component analysis in VSIPAL

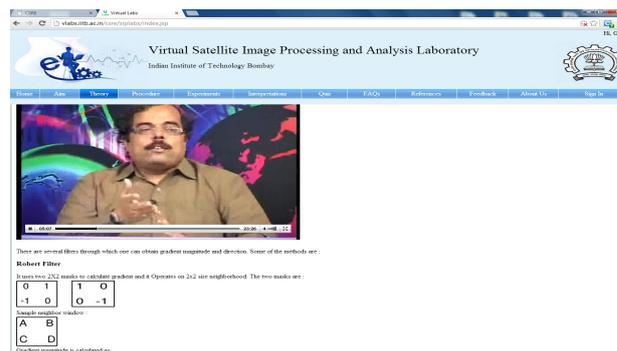


Figure 3. Multimedia lecture videos in VSIPAL

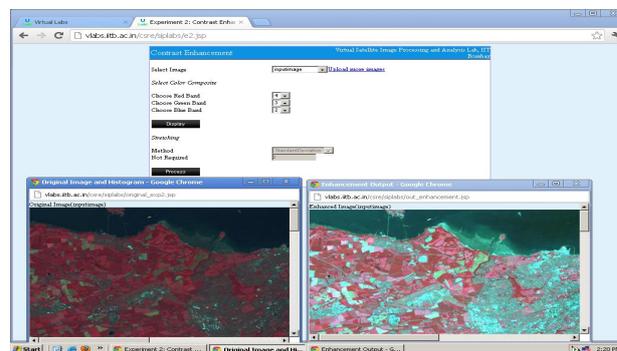


Figure 4. Image enhancement experiment in VSIPAL

3.3 Interpretation

It is a novel component where outputs of various experiments, using image samples provided along with VSIPAL, are discussed. Suggested user inputs are also provided. Developers of this virtual laboratory have executed each experiment and the output results are interpreted. This is meant to train or rather guide student/user to interpret result in order understand the information that could be inferred from the output result.

3.4 Quiz

This component is a self-assessment tool. It contains a number of multiple choice questions on related topics. It will reflect user's/student's level of comprehension in various topics listed in VSIPAL. More questions would be added regularly to this component. User/student is encouraged to suggest questions which will be included into the question database.

3.5 Uploading images

Though the experiments component is provided with image samples by developers, an user/student can upload images available with them. VSIPAL supports raw images with header files and images in bmp, tiff, jpeg/jpg, ENVI header and png format. The concerned link to upload images is provided at interface of an experiment. This uploaded image will not be visible to other users but only to the user who uploaded it. Apart from these features/components VSIPAL is also provided with step-wise details on executing each experiment in procedure component. Feedback component is for collecting suggestions from users to make VSIPAL better.

4. VSIPAL: ARCHITECTURE AND ITS IMPLEMENTATION

VSIPAL is an e-learning system, and hence it is developed for accessing its contents through internet. The user/student need only have internet connection to access the portal. There is absolutely no requirement for installation of any special hardware or software on user's computer. The Fig. 5 depicts this idea. VSIPAL is implemented on Windows Server 2003 operating system with Intel Xeon quad core processor. The server is equipped with 8GB RAM and one terabyte hard disk space. To start with, it was decided to conform to this minimum specification for enabling multi-user access to VSIPAL server at any given point of time.

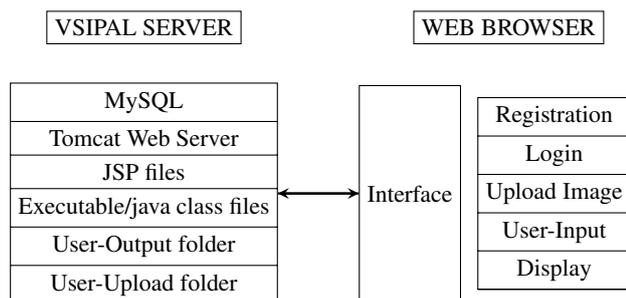


Figure 5. Interaction between host server and web browser

Development of any e-learning system will undoubtedly require knowledge of browser-server communication concept. Information stored on server in the form of HyperText Markup Language (HTML) pages, images and multimedia contents need to be displayed to a remote user through internet. Web browser enables a remote user to access a website by typing its URL in address bar of a browser. At the interface of the website one will find hyperlinks represented by icons or tabs. Clicking on these icons or tabs invokes web browser to create a request for the concerned web page on the server. The web server looks for the corresponding page in its database and formulates an appropriate response. The web server sends out the requested HTML page to the web browser which collects all the information related to the web page and displays them on client computer. Fig. 5 depicts browser-server interaction. The communication process for the hyperlinks provided for login, uploading images, user input, theory etc., all work as described with the help of web browser. It should be noted that the current VSIPAL system is most effective on Mozilla Firefox and Google Chrome web browsers.

VSIPAL's software architecture consists of a database server, web server and user space. The various components or software installed or scripts inside host server are MySQL, Apache Tomcat,

executables, java class files, JavaServer Pages (JSP) and user-folders. MySQL is used as a database system for storing and retrieving information. It is open-source software which enables multi-user access to VSIPAL server. Apache Tomcat is also an open source software used as a web server. It is the main component responsible for receiving requests, executing HTML pages and/or java server pages, and interaction with interface. JSP is utilized as web language for creating web pages based on HTML. JSP connects scripts, components and enables interaction of web server. Executables and java class files are program files essential in the execution of experiments i.e. hands-on experiments. User-output folder is where the outputs or results of different experiments are stored and is exclusive to a particular user. User-upload folder is where an image uploaded by user is stored. It is accessible to up-loader only.

Fig. 6 depicts interaction or the execution sequence that takes place between various components. When a user/student activates hypertext link it creates a request directed towards server for JSP or HTML pages. The server in-turn executes those server pages or HTML pages. For example, suppose that user wants to execute an experiment. As soon as the hypertext link is activated through browser, the corresponding JSP file gets activated. It in-turn activates corresponding executable file or Java class file for that experiment. Also, before activating executable files the image chosen by user is picked up by the program either from 'samples' folder or from 'user-upload' folder. The resulting output will be saved in the user's output folder, which was created while registering at the portal. Server is informed about the completion of the execution of experiment which in-turn informs the interface. As a consequence the output is displayed to the user through the interface.

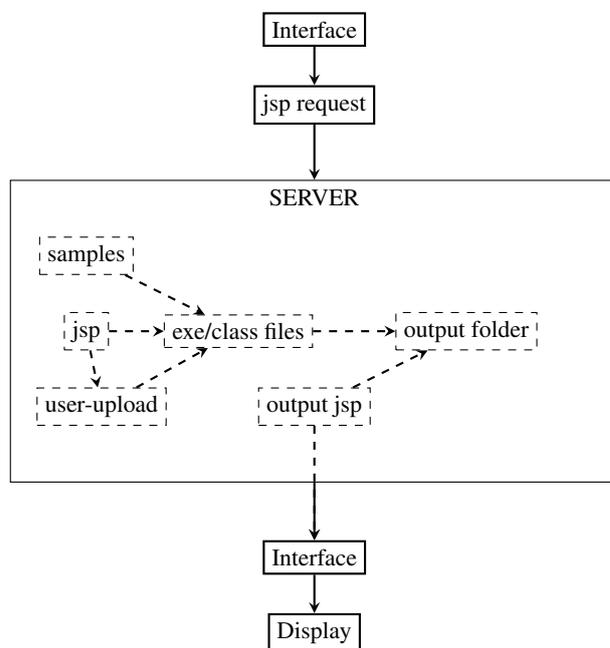


Figure 6. Process flow in VSIPAL system

As stated earlier in this paper, user can upload one's own images assuming it is one of the specified formats supported by the system. This new uploaded image is saved inside the user folder with name that user provides during registration. System creates user specific folders to avoid clashes between two or more users.

5. FEEDBACK

VSIPAL has been evaluated for its efficiency and user friendliness. Students of Indian Institute of Technology Bombay and from various other universities and colleges participated in the evaluation of VSIPAL. Feedbacks received have been positive. The following are the queries furnished in on-line feedback form.

To what degree was the actual lab environment simulated ?
The manuals were found to be helpful ?
The results of experiments were easily interpretable ?
Did you get the feel of "actual lab" while performing the experiments ?
Did you go through the manual/step by step method before performing the experiments live ?
Could you measure and analyze the data successfully ?
Could you compare your results with given typical results ?
Do you think performing experiments through virtual labs are more challenging than the real lab experiments ?
Do you think doing experiments through virtual lab gives scope for more innovative and creative research work ?
How helpful do you feel the system is ?
Specify problems/difficulties you faced while performing the experiments ?
Give most interesting thing about the experiments ?

Some of the responses received against query regarding helpfulness of the system are as follows,

"Any system of this sort will be more useful to the research labs/schools which has only internet and PC. System is too good for National Education System."

"Very helpful for students who do not have access to ERDAS, also helps to interpret the results in a better way"

"Since we can compare both original image and enhanced image by putting them side by side so it gives good feeling while performing the experiment"

Also, responses are positive for query regarding most interesting feature the users observed about the experiments. The following are some of them.

"Different color band analysis was fantastic"

"...different enhancement techniques at one place was very impressive. So comparison and interpretation became much simpler"

"All the experiments we can perform and test it at home on-line and we do not require any costly software package for the same"

"The most interesting thing was selection of subset coordinates which can be taken just by clicking the upper left and lower right corner of the image. Subset can be saved, this is also very useful"

Students expressed their appreciation and satisfaction with the functioning of VSIPAL. It is also reported that VSIPAL gives them flexibility to organize their schedule. Also, it is found that theory, procedure and interpretation components of VSIPAL reduce dependency of students on teaching assistants or tutors to great extent while performing experiments.

6. FUTURE WORK AND CONCLUSION

VSIPAL provides user-friendly environment to learn scientific concepts related to satellite image processing and analysis. It proves to be viable, cost efficient and effective way of introducing laboratory experiments to students spread across the globe. In addition, architecture of the system and its implementation described here in this paper can aid in the development of similar

virtual laboratories. From students feedback it is inferred that VSIPAL project is successful in providing a student friendly and effective learning environment. This e-learning tool can accompany as hands-on aid for a course based on standard text book such as Richards and Jia (2009). Also, it will save educational institutes with limited financial resources from buying commercial softwares related to satellite image processing. VSIPAL can be accessed for free at <http://vlabs.iitb.ac.in/csre/siplabs/index.jsp>.

In next phase of this project, advanced satellite image processing topics will be developed and provided on virtual laboratory. New topics that will be developed are data fusion, image compression, image segmentation, multi-resolution analysis using wavelets, support vector machine classification, hyper-spectral image analysis, fuzzy image processing etc.

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