FOREST MONITORING WITH REMOTE SENSING: A WEB APPLICATION FOR THE COMMON USER

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ABSTRACT

For a long time, accessing remote sensing technical materials through the Web was a difficult task due to lack of appropriate technologies. However, more recently, there has been an outstanding development in both hardware and software and Internet users are now confronted more and more with satellite data and image analysis tools through the Web. The problem is no longer how to access this type of material, but instead how to use and interpret it correctly. In fact, most users don't know how to extract information from the images they access and obtain via Internet. The use of satellite images for monitoring forest dynamics is of utmost importance for planning and maintaining this resource in a sustainable manner. Making the user aware of this process can empower him for better-based decision-making. In this study, a web application is developed to show the common user how satellite data can be utilised for forest monitoring, using high (e.g. Landsat) and very high (e.g. IKONOS) spatial resolution images. In particular, this application deals with forest cuts and new plantations and is designed with Java programming language, usable in different platforms. In our view, demonstrating the usefulness of satellite images to the common user can lead to an increase in their usage and to the development of Remote Sensing. The overall objective of this work is to make a contribution for a knowledge-based society, by narrowing the gap between the scientific and user communities, in the field of Remote Sensing.

INTRODUCTION

Portuguese Geographic Institute (IGP) and Portuguese Forest Services (DGRF) are working together in a project called "Using satellite images for automatic mapping of forest clear cuts and new plantations", hereafter referred as AGRO130. The main goals of this project are:

(1) to demonstrate the use of satellite images (Landsat and IKONOS) for automatic mapping of clear cuts and new forest plantations at local and regional scales;
(2) to demonstrate the usefulness of monitoring clear cuts and new plantations on information gathering (e.g. forest inventory, map updating) and decision making (e.g. planning and controlling environmental legislation compliance);
(3) to use Internet as an interactive tool between information producers and users.

The production of clear cuts and new forest plantations maps at regional scales is based on Landsat images whereas the local scale maps are produced with IKONOS multi-spectral images. In both cases (regional and local scale), one produces maps for two consecutive years in order to assure a significant number of clear cuts and new forestations to allow the validation of the mapping procedure. The methodology used for mapping clear cuts and new forestations is based on a change detection technique applied to the multi-temporal dataset – vegetation index image differencing. The vegetation index used is the NDVI (Normalised Difference Vegetation Index), which proved to perform well in previous studies.

Two demonstrators are developed and implemented in the project Web Site, using modern technologies for information manipulation. This paper is dedicated to the FORWEB demonstrator (Web demonstrator of Forest monitoring with satellite imagery) that shows how satellite images can be used for mapping clear cuts and new plantations. The platform independence, the evolution in performance, the number of classes readily available and the free use of this technology, made JAVA our option to build the demonstrator. FORWEB is more than a demonstrator because it contains real image processing analysis tools that can be applied to any type of satellite image. The other demonstrator will show the usefulness of monitoring clear cuts and new plantations for forest inventory, thematic cartography updating or environmental legislation compliance. This second demonstrator is based on an on-line Geographic Information System (GIS) that allows an interaction with the user though the Internet.

The Web demonstrators are implemented in the Web Site of the AGRO130 project. The site also includes basic remote sensing theoretical background to help the common user in the forestry domain to understand how satellite images can be used to derive maps of clear cuts and new plantations.

This paper has three main sections. In the first one we present the main web sites allowing on line satellite image processing. In the second section we present the methodology implemented in FORWEB for identifying clear cuts and new forest plantations with satellite images. In the third section we present the demonstrator developed with JAVA and JAI.

WEB SEARCH

A web search was performed to identify web applications related to remote sensing. To carry out our search in to the vast cyberspace, three common search engines were used, Google, Vivissimo and Taoma. The main conclusion is that there are not many web sites where the visitor can by himself and interactively use remote sensing data to derive information. Table 1 summarises the few web site exceptions that have satellite image on line analysis tools.

Table 1. Web sites with satellite image on line analysis tools.

ARC	**http://map.sdsu.edu/arc/Analytical_tools.htm**
	The goal of this project is to develop the capabilities for multiple users to conduct real-time analyses over the Internet using web-based software and geo-spatial data sets. Some of the functions available are, image overlay, temporal analysis and filters (Tsou, 2001).
HyperTool	**http://csugis.sfsu.edu/CSU/news0304/LosAngelesHypertool.htm**
	This Project has some basic on-line analysis capabilities to be applied to sample images of the Airborne Visible/ Infrared Imaging Spectrometer (AVIRIS) that are available in the Web site. Some of the tools available to explore de images include, RGB colour composition, perform spectral indexes calculations like, NDVI, photochemical reflectance index (PRI),water band index (WBI), and explore spectral profiles of different surface features (Qiu, 2004).
Hyperlens	**http://hyperdaac.webthing.com/html/viewer.htm**
	HyperLens is a tool for scientific image visualisation, and particularly Remote Sensing that can run on-line or as a stand alone application. The tool is free for personal use and was developed by webthing®. HyperLens is based on 'Lenses', which are a variant on the classic Layers.

The main conclusions derived from the performed web search are the following:

- Few web sites are directed to the common user and with learning objective. Some interesting tutorials of remote sensing were found, but often lacking the interactivity explaining the concepts.
- All sites that allow on line image analysis are conceived to users that are already familiar with image processing tools.
- All sites that allow on line image analysis are not oriented to a particular application domain, but are instead generic image processing tools.
- The majority of the results gathered that have some interactivity showed a preference in the use of JAVA technology in the form of applets.

The available web tools related to image analysis do not satisfy our two main needs: a demonstrator that allows on line image analysis by non-experts on remote sensing, and that, at the same time, is focused on forest monitoring. For this reason, and in order to reach our goal on showing the usefulness of remote sensing data for mapping clear cuts and new forest plantations, we decided to develop the demonstrator we present in this paper, i.e. the FORWEB.

THE METHODOLOGY FOR IDENTIFYING CLEAR CUTS AND NEW FOREST PLANTATIONS IMPLEMENTED IN FORWEB

The methodology selected to detect clear cuts and new forest plantations with satellite imagery is based on vegetation indices (VI) image differencing, i.e. a change detection technique. In this technique, a pixel of a certain band is subtracted from the same pixel of the same band, but in a different image date. The fundamentals for this technique rely on the idea that if VIs are related to biomass abundance then, the decrease/increase of vegetation can be detected by a difference of VI images (one before the land cover change and the other after that). Note that both forest practices addressed in this study, i.e. clear cuts and new forest plantations, are expressed by a decrease of vegetation. VI image differencing was selected as the methodology to implement in FORWEB because several authors report its adequacy, accuracy and efficiency as a technique for detecting changes in vegetation cover (e.g., Garcia-Haro et al., 2001; Armas e Caetano, 2005a). Furthermore, it is a simple technique and, therefore easy to understand by non-experts in remote sensing.

The development of VIs from satellite imagery's brightness values (BV) is based on the differential absorption, reflectance and transmittance of energy by vegetation in the red and near-infrared portions of the electromagnetic spectrum (Lyon and McCarthy, 1995). VIs show better sensitivity than individual spectral bands for vegetation detection (Bannari et al., 1995). Thus, measurement of vegetative amount and condition based on analysis of remote sensing spectral measurement led to the formulation of numerous VIs by operating mathematically on the imagery's spectral bands. These indices have been used for many purposes, including: assessment of deforestation (Banner and Lynham, 1981; Armas e Caetano, 2005a), mapping of burned areas (García-Haro et al., 2001; Armas e Caetano, 2005b), crop monitoring and yield forecast (Groten, 1993), estimation of percent ground cover and vegetative biomass (Tucker, 1979), and detection of changes in the urban-rural fringe. Studies confirm that VI differencing can be one of the most accurate change-detection techniques (Singh, 1989).

The selected VI to be implemented in FORWEB was the Normalised Difference Vegetation Index (NDVI) (Rouse et al., 1973) because of its simplicity and adequacy in vegetation abundance studies.

The methodology of FORWEB starts by calculating the NDVI for the two images covering the same area but acquired in different years. Then, one of these images is subtracted to the other, in order to derive the VI image difference. The changed areas (increase and decrease of vegetation) are on the tails of the distribution of the VI difference image, and therefore can be identified by descriptive statistic indicators (i.e., ? - mean and ? - standard deviation) (Figure 1). To identify the changed areas in the NDVI difference image, thresholds are selected based on the mean and standard deviation of the image difference histogram. This is a common procedure in land change use detection (e.g., Armas e Caetano 2005a). Several thresholds have been tested in the literature (e.g., ? ? 1?, ? ? 1.5? and ? ? 2?), and its selection is site and image specific. For this reason, in FORWEB the user can select different thresholds. Armas e Caetano (2005b) studies the effect of changing the threshold on the omission and commission errors of the changed areas.

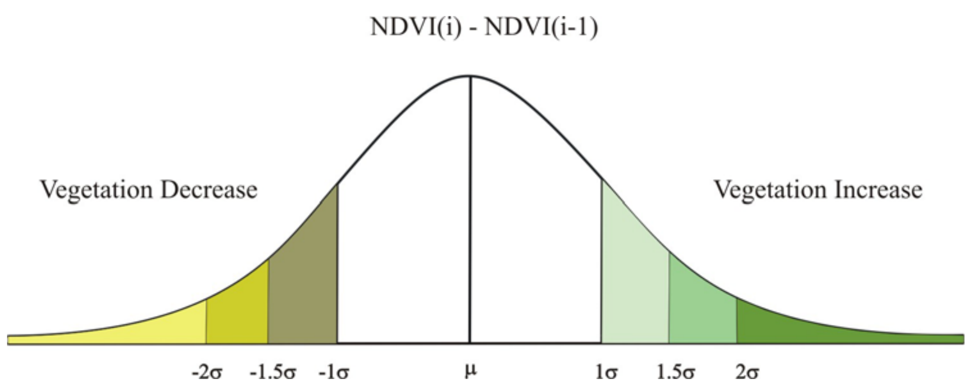

Figure 1. Illustration of the histogram of a VI difference image.

FORWEB DEMONSTRATOR

The demonstrator is based on the JAVA programming language version 5.0, using the Java Advanced Image v1.1.2 (JAI), Application Programming Interface (API), from Sun Micro Systems®. The development of the Guide User Interface (GUI) is based on the NetBeans® 4.1 Integrated Development Environment (IDE).

The GUI is divided in three major groups: Menu, Toolbar and Display Area. The Menu includes the image analysis tools for identifying clear cuts and new forest plantations. The Toolbar include general image navigation and visualisation tools. The Display area is where the image can be visualised, but detached frames can also be created.

Toolbar

The Toolbar includes several buttons that provide the user with navigation options, band histogram visualisation, pixel information query and the possibility to change the input bands for the Red Green and Blue (RGB) composites using three combo boxes (Figure 2). For the navigation option, functions are provided to zoom in and out over the image.

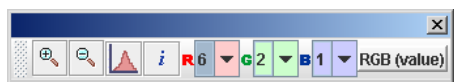

Figure 2. FORWEB toolbar.

The histogram button brings a new frame represented in Figure 3, where the user can analyse the different frequency of distributions for the visualised single band or for the three bands used in the RGB colour composite. The three combo boxes make it possible to use the bands in any order. The user can choose the band combination and experiment different composites to see how they change the visualization of the features represented by the satellite image. The “i” button allows the user to read the digital number of the bands used in the colour composite RGB. Figure 3 shows a Landsat image in the display area using a RGB 453.

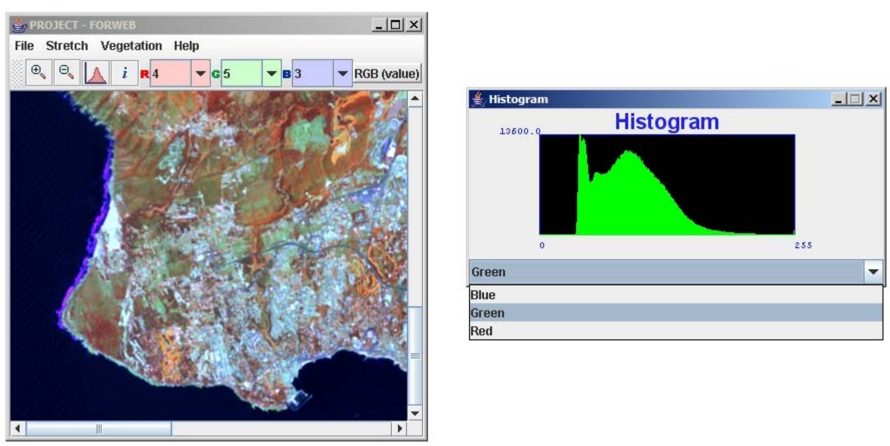

Figure 3. Overview of FORWEB and the histogram frame.

Menu

In the Menu there are at this time four options with which the user can interact: file, stretch, vegetation and help. The idea, again, is to keep things simple since FORWEB was conceived to be used by non-experts in remote sensing.

File Menu, provides the following options, open, save and image properties. The application can open and save most of the common image formats that are available directly by de JAI API, i.e. TIFF, BMP, GIF, JPG and PNG. These different image formats are sufficient for almost the entire beginner user needs. The application can use images that have more than 3 bands like the ones acquired by IKONOS, QuickBird and Landsat.

The Stretch Menu allows the visually enhancement of the loaded image based on the image statistics. In FORWEB the image brightness and contrast can be adjusted using linear contrast stretch techniques. The linear stretch translates the image pixel values from the observed range to the full range of the display device (generally 0-255, assuming a 8 bits display memory). There are three options available in this menu (Figure 4):

(1) Stretch [2std], corresponds to the visual enhancement operation where the mean (μ) and standard deviation (σ) are calculated to scale the pixel values. The result μ-2σ, define the zero in the display device and the μ+2σ defines the maximum value that will be used in the display device. In this option 5% of the lowest and highest values are transformed to 0 and 255 respectively.
(2) Linear Stretch translates the image pixel values to the full range using maximum and minimum pixel value to rescale the values to 0 and 255 in the display device.
(3) The option of visualising the image without any contrast or brightness enhancement thus showing the original pixel value.

The last option in the Menu group is reserved to the help, were an Instruction item is available and an About item that links to the project Web site.

Figure 4. The original image (left) and the images after applying linear stretch operations using maximum and minimum values (middle) and two standard deviation (right).

The Vegetation Menu includes items for calculating (Figure 5):
(1) Normalized Difference Vegetation Index (NDVI),
(2) differences (subtractions) of NDVI images,
(3) detection of forest vegetation decrease (i.e., clear cuts, new forest plantations, and forest fires) and increase (forest growth).

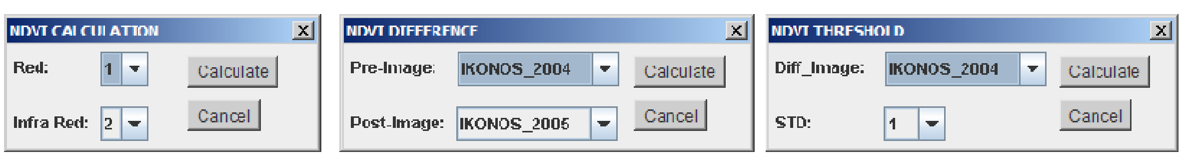

Figure 5. The buttons of the Vegetation menu of FORWEB.

The NDVI item pops a dialog in which the user can choose the infrared and red bands that will be used in the band ratio, and generate a new image. The image difference item allows the used to select two NDVI images of the same place but acquired in different moments in time. The item for detecting forest vegetation decrease and increase allows the user to select a threshold.

In Figure 6, we illustrate the use of FORWEB to identify clear cuts and forest plantations. The images presented in figure 6 were all calculated with FORWEB using IKONOS images from Central Portugal. The first two images on the first column are the RGB composites (4,3,2) of IKONOS images acquired in 2004 (top) and 2005 (bottom). The second pair of images corresponds to the NDVI images of the IKONOS imagery presented in the first column. As expected, forested areas and other vegetative covers have high values of NDVI and show up brighter in the NDVI image. On the other hand, areas with little vegetation cover have low NDVI values and are represented by dark grey. In the pair of images of the third column, we present the main output of FORWEB by presenting the vegetation increase (top) and decrease (bottom) maps. These last maps were derived by applying a threshold (□ □ 1.5□, in this case) to the difference image (NDVI2005 – NDVI2004). In the vegetation decrease map, the clear cuts and new forest plantations that could be visually detected in the previous images were automatically detected by the methodology implemented in FORWEB.

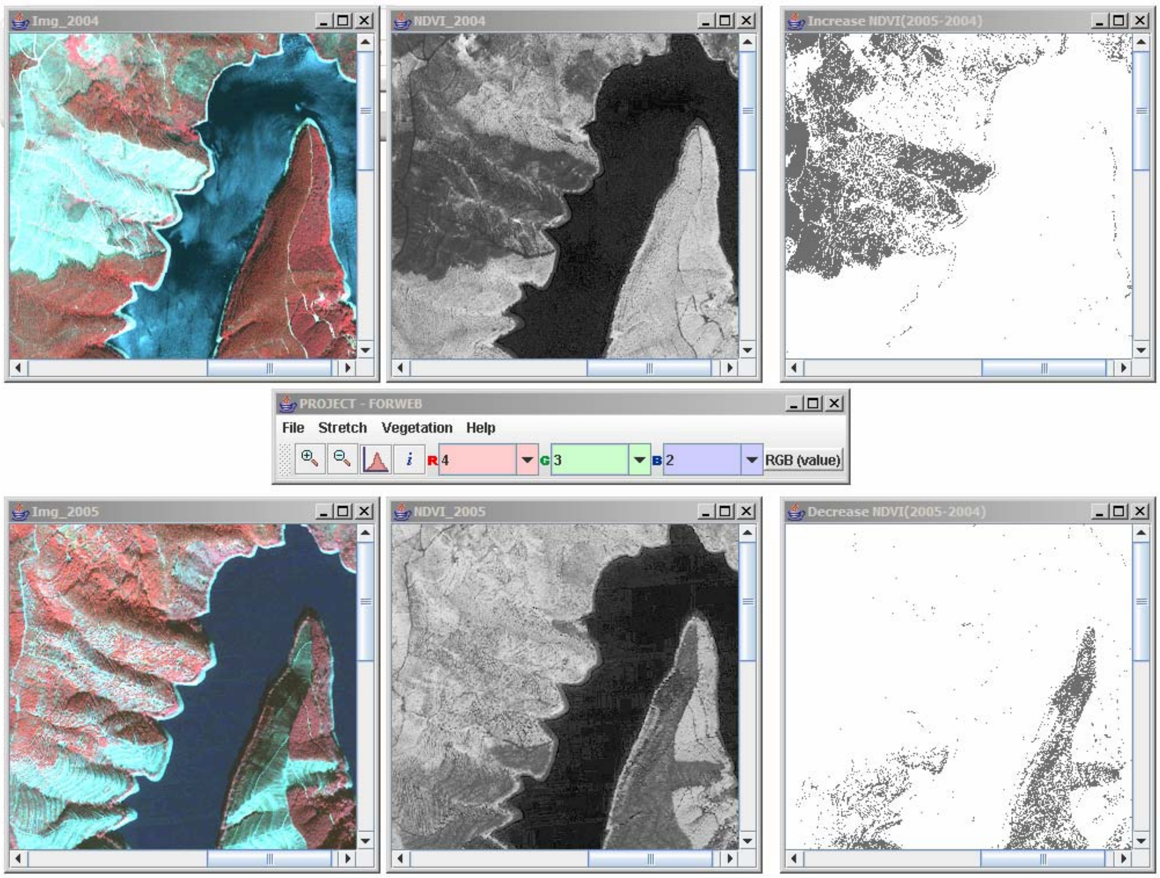

Figure 6. Illustration of the application of FORWEB to identify changes on forest cover in a area of Central Portugal with IKONOS imagery.

One of the goals of FORWEB is to illustrate the use of Earth Observation data to derive information at different scales. Landsat images are generally used to produce regional maps at scale 1:100000, while IKONOS imagery can be used to derive cartography at 1:10000 scales. Figure 7 illustrates the use of FORWEB for visual analysis of images from different resolutions. Four detached frames were created and in each one, images from two different satellites (Landsat and IKONOS) were loaded. The band combination RGB (4,5,3) was used, so features in the different images are represented in a similar colour. The upper left and right frames use a small scale to represent the IKONOS and Landsat image, and visually the difference between the two images is very small. In the lower left and right frames IKONOS and Landsat images from the same location were also loaded, but this time, with a higher scale. The user can now see major differences in the two images, and differentiate the forest cuts and plantation lines in the IKONOS but only individual pixel in the Landsat.

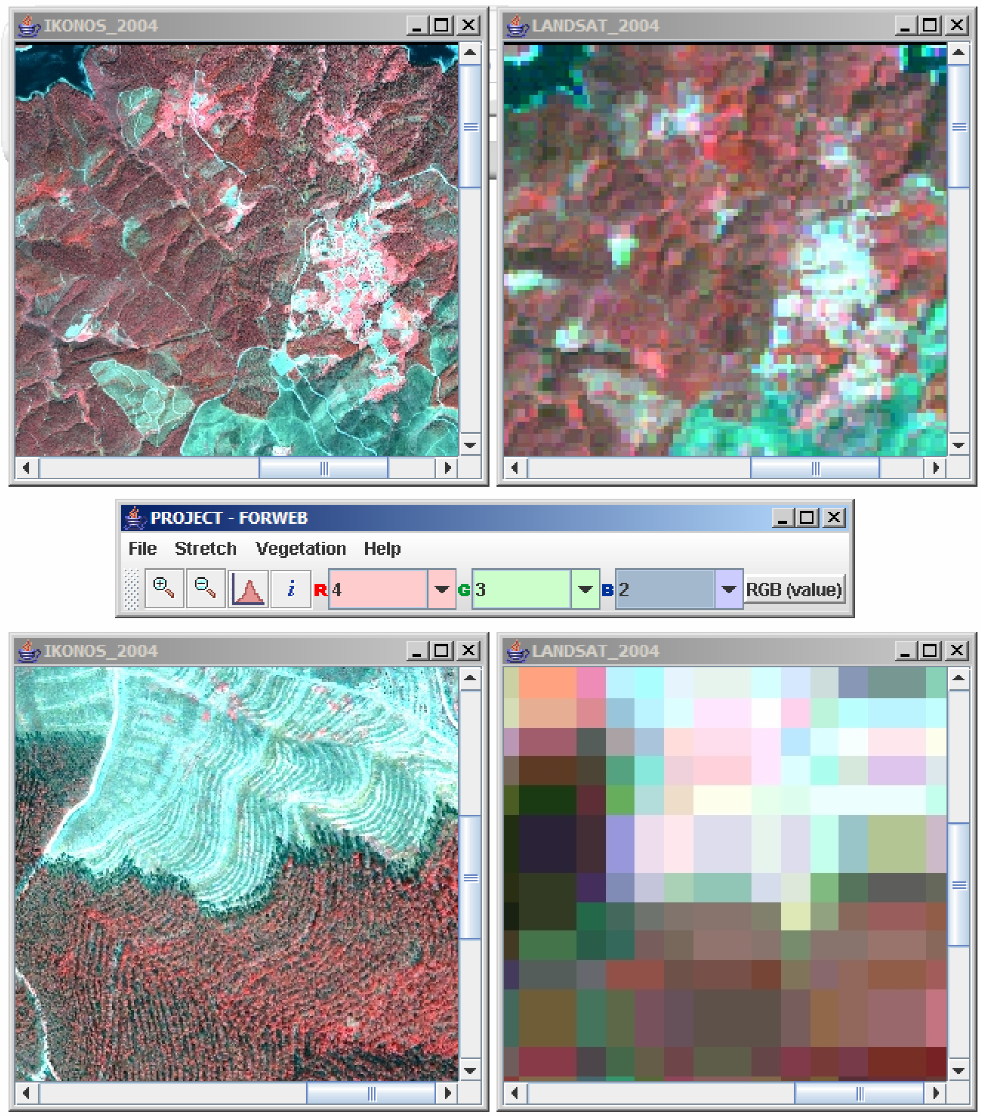

Figure 7. Illustrating the use of Landsat and IKONOS satellite images to derive information at different scales.

CONCLUSIONS

In this paper we presented the demonstrator FORWEB. This demonstrator is not intended to be a full remote sensing application, but instead an interactive application that gives the opportunity to the common user to visualize and carry out image analysis in order to extract meaningful information often used in planning and decision making.

The application can at this stage give some knowledge to basic analysis in the remote sensing, but still there are further developments and refinements that need to be done.

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