USING OPEN SOURCE SOFTWARE TO SUPPORT PHOTO-MONITORING OF ENVIRONMENTAL CHANGE

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ABSTRACT

Photo-monitoring can be used to document conditions across a landscape and is a valuable tool for resource and protected area managers. With this type of monitoring, photographs are used to document land cover and land use at a particular time or to record changes over time. Photo-monitoring can be used independently as a management/monitoring approach or it can be used in conjunction with aerial or satellite imagery to provide training and validation data for image analysis. Photo-monitoring techniques will be presented along with an explanation of different methods and software tools that can be used for geotagging digital images acquired with a consumer grade camera and a GPS receiver. These techniques and tools are being used in central Vietnam to monitor changes along the Ho Chi Minh Highway and in and around protected areas. We will present a summary of this project and to demonstrate how photo-monitoring can be used to support biodiversity conservation.

1. INTRODUCTION

Ground-based images acquired from either a digital or analog camera are an important data source that can be used to monitor environmental change over time. Although the process can be quite intuitive, photo-monitoring is still underutilized, both as a stand-alone monitoring tool and in conjunction with aerial or satellite imagery. Reasons for the underutilization of photo-monitoring include: lack of knowledge of proper techniques for conducting photo-monitoring, lack of user-friendly software for analysis of photo-monitoring images, and a lack of standard protocols for recording, archiving and sharing digital images.

In its simplest form, photo-monitoring involves using a camera to acquire repeat images of the same scene from the same vantage point and analyzing the resulting collection of images to denote changes. As a stand-alone tool, photo-monitoring can be used for different types of monitoring situations. For example, images can be used for monitoring landscapes, small plots, and events. Monitoring landscapes over time usually involves collecting a series of images to measure changes in land cover driven by anthropogenic activities such as deforestation, burning and the dynamics associated with swidden agriculture. Monitoring small plots involves viewing relatively small areas (often on the order of one or several square meters) and can be used for monitoring changes in herbaceous and

shrub ground cover. Using small plots in marine environments is also possible for tasks such as monitoring coral recruitment or bleaching. Event monitoring is designed to monitor a specific event such as erosion or rehabilitation of a particular area and can utilize techniques used for landscape or spot monitoring.

Used in conjunction with satellite or aerial imagery, photo-monitoring techniques can be used to support land cover change mapping work by providing information that can be used for training and validation of classification activities.

2. OVERVIEW OF PHOTO-MONITORING

Many of the same techniques that are used for working with analog (paper) photographs are still used for working with images acquired using a digital camera. Frederick Hall of the United States Forest Service (USFS) has written two excellent guides detailing methods for photo monitoring; Ground-Based Photographic Monitoring (Frederick C. Hall 2001) and Photo Point Monitoring Handbook (Frederick C. Hall 2002). Both of these documents are available for free download from the USFS Pacific Northwest Research Station Publications and Products web site: http://www.fs.fed.us/pnw/publications/gtrs.shtml.

Hall recommends that five basic questions should be asked before developing a photo-monitoring project:

- ***Why*** is monitoring necessary? This defines the goals and objectives of the project. The remaining questions require a good definition of "Why" before they are answered.

- ***Where*** will the monitoring take place? Defining the place that will be monitored is usually straightforward after defining the goals of the project.

- ***What*** event, land cover type, or landscape will be monitored? What will be monitored requires careful thought and will strongly influence the answers to the following two questions.

- ***When*** and how frequently will images be acquired? Determining "When" to monitor must be decided carefully to ensure that images of the features or events are acquired at times (hour of the day and day of the year) and frequency that are optimal for monitoring the features defined in the "What" question.

- ***How*** will the monitoring project be accomplished and what techniques will be used? This step involves selecting appropriate techniques for monitoring. To accomplish this, it is necessary to select methods for; recording, organizing, and analyzing the photographs that will be used for monitoring. This is the step where open source software tools have the greatest impact.

A basic principle in any kind of monitoring is to collect a baseline data set from which changes can be measured. This initial step in the photo-monitoring process must be carefully documented so that successive images of the site can be acquired properly. Required information for each image includes: coordinates of the imaging point (i.e., where the camera

was then the image was acquired), the direction and inclination that the camera is pointed, and the camera settings.

The point from where an image is acquired is called a "photo-point" and sufficient information must be recorded to ensure that someone can return to that exact point. To start with, it is a good idea to record the geographic coordinates of the point using a GPS receiver. In some cases this will be the most accurate way to record the point location but other information can also be helpful. In addition to geographic coordinates it can be useful to create a sketch-map showing the location of the photo-point. The sketch map can show the distance and bearing from fixed objects such as trees, rock outcrops, or other features that would be easy to find if within the general area. To be absolutely sure that the same location is used it is best to establish, if permitted, a fixed marker or use existing markers such as kilometer markers along a road. A fixed marker can be created using steel rebar and it can be made discrete enough so it isn't stolen and can be located using a metal detector.

The direction and inclination of the camera should also be recorded. One way to ensure subsequent images have the same camera orientation is to create a mount, such as a tripod hat can be used to hold the camera (Figure 1). In the field the mount is oriented using a compass to set the direction of the stage and an angle device to set the slope of the stage. Once the direction and inclination are set the camera is placed on the mount and the picture is taken.

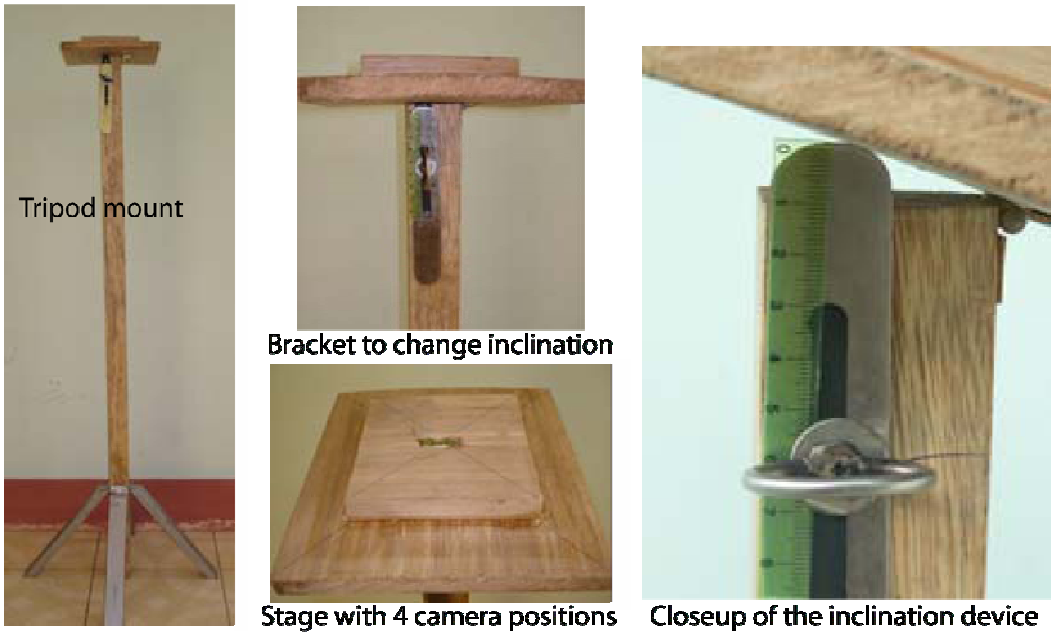

Figure1. Mount and stage used for photo-monitoring.
Images courtesy of the Green Corridor Project Hue, Vietnam.

It is also important to save information about the camera settings such as focal length, zoom level, aperture setting, and camera make and model to ensure that comparable images are taken during successive collection events. When using a digital camera, some of the camera parameters are saved along with the image but it is still a good idea to record this information on the site description form.

Although the methods promoted by Hall (2001) and others work well for analog photography it is hoped that new tools will soon be developed that are designed to work with digital photography. Such new tools have the capability of revolutionizing photo-monitoring techniques. Some areas where these new tools can make a difference are: streamlining the geocoding process, a database to easily store and share imagery, and improved visualization and analysis capabilities that use state-of-the-art digital image processing techniques.

3. OPEN SOURCE SOFTWARE FOR PHOTO MONITORING

Open source software is defined as software that is licensed to guarantee that the source code is freely available and so that it can be freely distributed and modified as long as appropriate credit is provided to the original developers. A number of open source software tools that can be used to support photo-monitoring will be discussed in this section. These tools fall into the following categories: geocoding digital images and linking and visualizing digital images in a Geographic Information System (GIS), storing and organizing digital images. Storage and organization of images is beyond the scope of this paper but one promising project worth keeping an eye on is the digiKam project: http://www.digikam.org/ since it has the ability to geotag images and locate the coordinates stored in the image on a map.

Geocoding an image by attaching geographic coordinates of the position from which it was acquired is called geotagging and can be accomplished in different ways. One approach is to use a camera that is GPS enabled to automatically store the coordinates with the image. This option is gaining in popularity but is still not very common. Another approach is to geotag the images with coordinates after the image has been acquired. To do this it is necessary to record coordinates with a GPS receiver at the same time the image is being acquired. These coordinates can then be manually entered into image metadata. If the GPS data can be downloaded to a computer some applications provide the ability to synchronize the time-code recorded by the GPS receiver and the camera to automatically assign the correct set of coordinates to each photo.

GPicsync (http://code.google.com/p/gpicsync/) is designed to geocode images acquired with a digital camera using GPS track data that was acquired while the images were acquired. There are a few options but in general you need to specify the location of the GPS track file in your computer, the directory where the photos are located, and data to synchronize the time code from the track file and the images. This time synchronization is necessary because the clock in the digital camera and the GPS receiver are almost certainly not exactly the same. Synchronizing the time codes is done by entering a time recorded from the camera and the corresponding time displayed by the GPS receiver. A simple way to do this is to take a picture of the GPS receiver screen displaying the time. GPicSync has a utility that makes it possible to read the EXIF (metadata) data in the digital image that contains the time and date when the image was acquired. Entering the time stored with the image EXIF data and the time displayed in the image of the GPS receiver (this can be seen in the image) GPicSync is able to calculate the offset between the GPS receiver and camera clocks. For each image GPicSync updates the EXIF data by adding the geographic coordinates recorded at the closest time to when the image was acquired.

One requirement for using GPicSync is that the positional data must be in the GPX or NIMEA file format. If positional data are not in a usable format, a program called GPSBabel (www.gpsbabel.org/), which is capable of converting dozens of GPS file formats, can be used to translate the positional data into a usable format. When you download GPSBabel you will notice there is a GUI program in addition to the command-line version.

A handy pair of programs for editing the EXIF data in a digital image is ExifTool (http://www.sno.phy.queensu.ca/~phil/exiftool) and ExifTool GUI (http://freeweb.siol.net/hrastni3/foto/exif/exiftoolgui.htm). These EXIF editing tools can be used to apply changes to EXIF data several images at a time. For example, it is possible to change the date for all images residing in a directory which can be useful it the camera's data and time are not set properly.

Once the images have been geotagged it is possible to link them to a GIS. One open source GIS package that supports this type of linking is Quantum GIS (QGIS: http://www.qgis.org) and the eVis plugin (http://biodiversityinformatics.amnh.org/open_source/evis/index.php). Using eVis it is possible to load an ESRI Shapefile with points of the locations of where a set of images were acquired from and then by clicking on one of these points the images associated with that point are displayed. With eVis and QGIS it is possible to display the locations for all photos acquired for a particular photo-monitoring project and then open them by clicking on their associated point.

Additional tools are being developed by the American Museum of Natural History's Center for Biodiversity and Conservation Biodiversity Informatics Facility (http://biodiversityinformatics.amnh.org) that will simplify the process of geocoding and integrating photo-monitoring images in a GIS environment. One such tool is a native EXIF vector data provider that will automatically create a point vector file with attributes from information stored in image EXIF data. There is also a tutorial on using the tools described in this paper available at: http://biodiversityinformatics.amnh.org/index.php?section=osr_cbc_tutorials.

4. CASE STUDY FROM CENTRAL VIETNAM

In central Vietnam, the Ho Chi Minh Highway (HCMH) project funded by the DANIDA project, "Increasing local capacity to mitigate the impact of the Ho Chi Minh highway on the natural and social environment of the Central Truong Son", is using photo-monitoring methods to monitor changes along a portion of the highway. The project is implemented by the WWF Greater Mekong Programme and the Forest Protection Departments of Quang Tri, Thua Thien Hue, Quang Nam and Kon Tum provinces. This example addresses all of the Why, Where, What, When, and How questions mentioned above.

The goal of the photo-monitoring project was to acquire repeat images using digital cameras to detect and determine the impact from changes in forest cover as well as erosion along the road. Specific objectives included:

- Identify, monitor and mitigate impacts related to the HCMH on the natural and socio-cultural environment of the Central Truong Son Mountains.
- Monitor the number, size, and location of activities, such as fire, logging, re-vegetation, livestock grazing, and erosion to improve management capabilities.
- Provide data to support effective highway impact mitigation.

A sampling designed was developed to establish systematic photo-points at even-numbered kilometer markers along the roadside. Portions of the HCMH passing through towns were excluded since little if any natural areas remained to be monitored. In addition to the systematic points, additional, deliberately placed points were established to monitor specific events such as erosion, newly built houses, forest restoration, and tourist trails where changes were likely to happen.

At each site a GPS receiver was used to record the UTM coordinates for the photo-point. The camera mount was oriented so that the camera would be facing the northbound direction and roughly parallel to the road. Next, the slope of the up-slope and down-slope sides of the road was measured. The default setting of the focal length of the camera was used (i.e., the zoom feature was not altered). All of this information was recorded on a form to ensure accurate camera location and orientation on successive trips.

At each of the systematic points four images were acquired, each offset by 90 degrees, using a digital camera. To ensure proper camera placement the stage which holds the camera is designed with a square block in the middle. For each shot the back of the camera was placed against a different side of the block (Figure 1).

Images were acquired at the following five time periods: May, 2007, December, 2007, February, 2008, and May, 2008 and July, 2008. The images were acquired between 9:00AM and 3:00PM and for the deliberately placed points an effort was made to aim the camera away from the sun. A file naming convention was developed to record a unique identifier for each point and the date. For example, photo 256N26may2007.jpg was recorded at kilometer marker 256N on 26 May 2007.

Preliminary results indicate different types of change:

- Changes in forest cover – deforestation and forest restoration
- Changes in the infrastructure such as retaining walls
- Erosion
- Areas that have been impacted by the road and areas that have not been impacted

Work is currently being done to measure the extent of some of the changes that have occurred and a report is being generated to summarize the results.

REFERENCES

Frederick C. Hall, 2001. *Ground-Based Photographic Monitoring*, Pacific Northwest Research Station: USFS. Available at: http://www.fs.fed.us/pnw/pubs/gtr503/.

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