A Southeast Asia Web-based GIS Fire Mapping System

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Abstract: In this paper, we describe a web-based GIS to map hot spots and fire in the Southeast Asia region. The system is developed using an opensource software called Mapserver which is best suited for construction of spatially-enabled web applications. There are several layers of information available including a realtime and archived hot spot database. Realtime and archived true colour MODIS images as well as high resolution imagery from SPOT or ASTER can be overlaid subject to availability. A MODIS land cover product (MOD12Q1) is an additional layer that provides land cover information over the hot spot location. A global digital elevation model called GTOPO30 provides altitude information at the hot spot or fire location.

Keywords: WebGIS, MODIS, Fire, Hotspot.

1. Introduction

In Southeast Asia, fire is a convenient tool used for small-scale land clearing as well as large-scale commercial land conversion activities. During the dry season, some fires burn out of control resulting in the smoke and haze spreading beyond the country boundaries to neighbouring countries. During the severe El Nino episode in 1997 [1], severe transboundary smoke and haze from Indonesia severely curtailed and disrupted economic activities in the neighbouring countries. In the aftermath of the disaster, the Association of Southeast Asian Nations (ASEAN) countries set up a task force to prevent the future occurrence of such events. Singapore has taken up the task of fire monitoring for the region.

Before the advent of MODIS instrument, the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) was the preferred sensor for global fire detection. The channel 3 band of AVHRR is sensitive to high temperatures but saturates at a relatively low temperature of 317K. Despite that, it was found that many fires in the 1997 event were undetected by the existing fire detection algorithm. Nakayama et al [2] investigated the shortcomings of the AVHRR fire detection algorithm and adapted the algorithm to Indonesia.

With the launch of the TERRA satellite in 1999, MODIS Direct Broadcast (DB) became available. DB enabled countries with a limited size antenna to downlink the MODIS data realtime. The MODIS sensor has a high temperature-sensitive band similar to the AVHRR. Although MODIS is a science instrument, it quickly became the preferred sensor for fire detection because of the much higher saturation temperature of this band. In addition, the satellite's geolocation accuracy is much better than the AVHRR. Lim et al [3] described the initial setup at CRISP to process the DB data. With this capability, CRISP was able to do near realtime fire monitoring for the entire Southeast Asia.

In 2003, NASA released the MODIS institutional algorithms to process MODIS level 2 products from Level 1. One of the products is MOD14, the active fire detection algorithm. Low et al [4] described the setup of a web portal to display near realtime level 2 products. Although the portal is currently not available on the internet, it is operationally used for planning and acquisition of very high resolution SPOT data over suspected fire locations. Whenever new MODIS overpass is available, a unix script is triggered to process the raw data to Level 1 and subsequently to Level 2 products such as hot spots. On completion, a hot spot text file and a true colour jpeg image are being pushed to the web server. If a significant number of hot spots are detected in Sumatra or Kalimantan, the duty personnel will plan the next available
SPOT overpass to image the location of the fires. As SPOT has imposed a daily cut-off time for the next day's SPOT acquisition plan, the latest realtime MODIS data is critical for the decision making.

To date, there are several fire web applications available. Most users are aware of the Global Web Fire Mapper which displays active fires detected by the MODIS Rapid Response System (http://maps.geog.umd.edu/). This is a collaborative effort between National Aeronautics and Space Administration (NASA) Goddard Space Flight Centre (GSFC) and the Department of Geography, University of Maryland. The user can choose a global map or one of several regional maps to view the fires. The user is prompted to select various vector and raster geographic information layers before proceeding to the display page. The final display is a java applet which allows the user to zoom in and out as well as turn on and off the different layers of information. The hotspot information for the Southeast Asia region at this website is delayed by several hours due to MODIS satellite data downlink.

Closer to the Southeast Asia region, Australia has the Sentinel Hotspot (http://www.sentinel.csiro.au/sentinel.html) System. This system provides timely fire location data to emergency service managers across Australia. Like the global Web Fire Mapper, this system displays fires detected by the MODIS instrument. While the Global Web Fire Mapper experiences a time delay as a result of data downlink, this system is able to process the Direct Broadcast (DB) data and avails the hot spots immediately to the user via the Sentinel website.

To enhance the current capability and delivery of fire information to users, CRISP has setup a fire web GIS system similar to Australia's Sentinel system. Both the NASA Web Fire Mapper and Australian Sentinel Hotspots systems [5] are developed with well-established 'off the shelf solution'. However, our system is built in-house based on opensource software. Nowadays, the availability and quality of opensource GIS software is challenging the costly 'commercial off the shelf' (cots) solutions. The pros of cots are a shortened development time, software support and greater availability of expertise in multi-agency collaboration. On the other hand, opensource software requires a relatively steeper learning curve and in an operational environment, is still perceived as unreliable. In a web-based environment, applications need to be robust to handle the potentially high traffic at the website. Fortunately, in many instances, opensource applications have performed just as well as the cots packages. As the system here is a prototype, this paper will not address the issue. Suffice to say that many opensource solutions are already being deployed on the internet and have proven their effectiveness.

2. MapServer Software

The web GIS system is built on MapServer (http://mapserver.gis.umn.edu/), a very successful opensource solution. MapServer was originally developed by the University of Minnesota (UMN) in 1994. Since then, the technology has been made available to many organisations and has grown rapidly through a dedicated and sizeable community of developers on the internet. At the point of writing this paper, MapServer is at version 4.6.1 and is still evolving. When the project was initiated in May 2005, it was at version 4.4.1.

MapServer builds upon several very successful opensource projects. Data access is achieved through the Geospatial Data Abstraction Library (GDAL) package [6] which contains the essential raster and vector file handling functionalities. The projection tools include the PROJ4 cartographic projection library [7] originally developed by the US Geological Survey (USGS). MapServer is designed to do two main functions over the web. First, it can create maps and associated products like legends, scale bars and secondly, it can query spatial data.

MapServer has two primary components: one is a Common Gateway Interface (CGI) component called 'mapserv' and the other is an Application Programmable Interface (API) called MapScript. The latter provides greater flexibility because function calls can be invoked from popular programming languages such as PHP, Python and Java. For the developers' convenience, wrapper classes for several of such popular languages have already been developed and are included in the package.

The web-based GIS system is implemented in Java language. In the code, the program uses the Java wrapper classes to access the native routines for setting up parameters and drawing the maps as well as querying the data.

3. Web-based Content

The aim of the web GIS system is to provide users of limited internet bandwidth capability with the latest available fire and hotspot information. MODIS DB processing at CRISP is fully described in Low et al [8]. On completion of data processing, hotspot products are stored on the web server. Simultaneously, hotspot emails are sent to subscribing users.
The web GIS system is expected to enhance the current process by adding spatial context through addition of important map layers. These extra map layers will provide information about features in the vicinity of the hotspots which should assist the users in decision making.

For a start, the system will include layers such as the hotspot locations, corresponding MODIS true colour raster image, topographic map, MODIS land use map, a country and administrative boundaries vector layer and very high resolution imagery from SPOT or ASTER if available. Additional vector layers of roads, river network, etc may be added in due course when they are available.

3.1 Hotspots

The current hotspot locations are produced by NASA MOD14 fire detection algorithm. The current version of the algorithm is 4.3.2. The hotspot data from each MODIS overpass is stored in shapefile [9] format. This facilitates the input to the MapServer software which accepts this vector format. Another advantage is that this format is readily accepted by many GIS software. The latitude and longitude values are stored as shapefile point type, while the MODIS bands 21/22 (3.9 micron) brightness temperature, bands 31 (11micron) brightness temperature as well as its corresponding average background temperatures are stored as attributes in the shapefile's database table. Such attributes will provide for ad-hoc studies and further understanding of hotspots characteristics in the region. One such study done by CRISP to validate the performance of the NASA fire algorithm in the Southeast Asia region is described in Liew et al [10]. Currently, CRISP is also actively developing new fire algorithms to detect fires in the region.

3.2 MODIS true colour image

Oftentimes, the hotspot data by itself does not reveal the ground situation. Cloud may obscure some hot spots or the overpass precludes some area in its coverage. Under the circumstances, an image either in false or true colour, will provide useful contextual information and assist in the interpretation of the hotspot data. Recognising that fact, a true colour image at 1 km resolution is generated during the hotspot processing run. It uses the MODIS band 1 (0.65 micron), band 4 (0.55 micron) and band 3 (0.47 micron) assigned to the red, green and blue colour combination respectively. By superposing the hotspots on this image, the user can infer the atmospheric conditions at the time of satellite overpass. The presence of smoke plumes emanating from the hotspot can further validate the hotspot as well as reveal the prevailing wind direction. Furthermore, the true colour image is useful for delineating the smoke haze coverage extent caused by the hotspots.

3.3 Southeast Asia Country and administrative boundaries

The country and administrative boundaries can be overlaid if available. Examples of other map layers include roads, rail, rivers, etc. The Global Fire Web Mapper website provides a set of vector map layers for the Southeast Asia region [11].

3.4 GTOPO30 Digital Elevation Model

The GTOPO30 (http://edcdaac.usgs.gov/gtopo30/gtopo30.asp) is a global digital elevation model (DEM) with a horizontal resolution of 30 arc seconds (approximately 1 kilometre). The Southeast Asia raster layer used here is a mosaic of two tiles (E060N40 and E100N40) downloaded from the above website. A simple classification scheme is applied according to the elevation height. When this map layer is active, the user can estimate the height at the location of the hotspot by referring to the legend displayed.

3.5 MODIS Land Cover

The MODIS Land Cover Data Product (MOD12Q1) (http://geography.bu.edu/landcover/) provides a suite of global land cover classification with the primary classification based on the International Geosphere-Biosphere Programme (IGBP) scheme. A user manual, provided at the website, gives a comprehensive account of the product and its retrieval algorithm. Essentially, the land cover algorithm uses twelve months of MODIS Level 3 products such as the Nadir BRDF Adjusted surface Reflectance data (NBAR - MOD43B4), Enhanced Vegetation Index data (EVI - MOD13A2), Land Surface Temperature data (MOD11A2), BRDF information (MOD43B1), and surface texture information (MODAGTEX), and a global set of training data to provide a global classifications of the land surface. The latest available land cover data is derived from MODIS data between 1 January 2001 and 31 December 2001. The data has a 1
kilometre resolution. This map layer is used to provide land cover information at the location of the hotspot. When the layer is active, a legend will be shown which associates a colour to each IGBP class.

3.6 High Resolution Imagery

MODIS has a wide swath coverage and is suited for daily monitoring of hotspots in the Southeast Asia region. However, fires are normally of sub-pixel resolution and despite its good geoaccuracy, MODIS is unable to provide the precision needed for fire suppression activities. In order to locate the fires with high precision, high resolution imagery such as SPOT or ASTER is required. SPOT imagery has a resolution of 20m or better while ASTER is 15m or 30m. SPOT data is received and processed regularly at CRISP to service commercial requests. Whenever a significant number of hotspots is detected over an area or region in Sumatra or Kalimantan, a SPOT data acquisition is requested over the specific area at the next available SPOT overpass. Immediately after the SPOT data is received, it is analysed for fires. Detection of fires on SPOT is done via visual recognition of certain fire signatures like smoke plumes or reddish pixels.

A useful technique to 'ground truth' hot spots is to overlay them on such SPOT images. It is also possible to derive other characteristics like land cover and wind information through examination of the fires on SPOT data.

4. System Concept

The web-based concept provides efficient delivery of hotspot data to users in a simple and convenient way. The user is not required to install specific software to access the data. The requirement is a java-enabled browser which is relatively commonplace nowadays. The user is presented with a java applet interface that has the following characteristics:

a. A thumbnail image to navigate the area of the view.
b. A slider to choose the scale of the view, ranging from a Southeast Asia wide region (approximately 1:25 000 000) to a local region scale (about 1:250 000)
c. Another slider to choose the size of display, from 400 by 400 pixels to 600 by 600 pixels.
d. Several map layers, as described earlier, which the user can turn on or off.
e. A set of controls to choose the satellite, either Terra or Aqua, and date/time of the MODIS overpass.

The server end consists of a web server which can process Java Server Pages (JSP) and Java Servlets (see Fig 1). The web server in use is the opensource Apache Tomcat engine. In addition to hosting the web server, this computer also provides storage capacity for the daily hotspot shapefiles, MODIS true colour JPEG overpass images and their corresponding world files, as well as the other important map layer files. In the prototype setup here, the server runs in a Linux Operating System environment. In order to run MapServer, all the opensource packages specified in section 2 are required. These packages need to be downloaded from the mapserver homepage and compiled properly before MapServer can be installed.

Any MapServer web application will require a configuration file known as a 'mapfile'. A mapfile is a text formatted file detailing the file paths of the data and all the map layers including map projections, legends, scale ratio, etc. Each layer has a specific name and is characterised by a set of attributes such as line colour, symbols, etc. A full description of the attributes comprising a mapfile can be found in the MapServer documentation which is available on the internet.
The user (client) interface is a HTML document with a frame layout (see fig 2). The left frame is a java applet which provides the control and navigational capabilities. The right frame is a static display of the map which is updated immediately as the user interacts with the java applet. Figures 3, 4, 5 and 6 shows various capabilities of the java applet including zooming and map layer selection.
Figure 3. Interface shows the maximum extent of the map area with hotspot, MODIS JPG image and Land cover layers.

Figure 4. Interface shows the maximum extent of the map area with hotspots, MODIS JPG image and GTOPO30.
5. Conclusions

A web GIS system has been developed to deliver fire and hotspot related information in the Southeast Asia region via the internet. It builds upon the existing capabilities of CRISP to process MODIS Direct Broadcast data in realtime. The system is developed using the opensource software MapServer. Currently, the system is being evaluated and used internally for fire monitoring. It is a flexible system allowing more GIS layers to be added when necessary. This system can be customised to another region relatively easily by changing the mapfile parameters.
References


