Developing new tools to do our work

New technology-driven tools are available almost daily that allow us to better understand the world and communicate that understanding. Computing power has reached levels scarcely imaginable only a couple of decades ago and technologies such as GIS take advantage of the enormous data sets electronically available to live up to their acclaimed potential. Satellite images paint the earth using digital snapshots at remarkable resolutions. Geoscientists are rapidly looking for new ways to use these images for interpretation and to provide context to the interpretation of specific events.

We reported in the fall of 2008 some of the outcomes of change detection analysis on Vancouver Island (Fall 2008 Link), but in the meantime, MOE has been partnered with the University of Calgary to test a new automated method of change detection for large areas. The tool called LCM, or land-cover change mapper, uses some innovative object-based methods to create change polygons that can be used on their own, or as an initial step in the interpretation process. It is primarily designed to detect polygonal changes rather than linear changes (cutblocks, cleared areas for development or large burns are easier to detect than roads or landslides for instance), but it does so with tremendous accuracy and in a matter of a few seconds, and best of all, the program is freely downloadable from the U of C website. I’m really excited to be able to showcase the results of this test in Island Geoscience this quarter. The article is a brief summary of a longer paper that can be found in the reference section.

It’s my hope that you find it interesting and potentially useful.
Land-cover Change Mapper (LCM): How object-based change detection mapping can improve landscape management.

Monitoring changes in the landscape is a prerequisite for sustainable land management and environmental monitoring. Remotely sensed imagery, with its timely and synoptic view of the Earth’s surface is an excellent source for spatial change analysis. Despite the many change detection algorithms developed, however, most government agencies still rely on photo-interpretation or field exercises to fulfill their monitoring mandates. A possible reason may be that to date, there is no strong conviction that automated processes are sufficiently accurate to be used at an operational level. New evidence suggests, however, that object-based change detection can provide the required increased accuracy.

Object-based change detection is a process whereby the images are not merely seen as a series of pixels, but are rather parsed into objects, based on similar digital signatures, and analyzed by both their individual pixel values, and the spatial attributes of the object such as texture, context and shape (Hay and Castilla, 2006). Object-based change detection has the advantage that large areas can be assessed automatically using decision processes that are similar to a human based interpretation methodology. However, the rules around how a computer will combine pixel-based data into object-based data are complex and the usefulness of the results may vary as a consequence. To date, there is no automated system able to exploit the entire suite of interpretative criteria employed by a skilled analyst. Since significant research remains until fully automated image interpretation is achieved, the short-term goal should be to support analysts in generating timely, consistent, and accurate products with tools that increase their productivity. Such tools should be easy to use, inexpensive, and should not require elaborate fine-tuning by the interpreter.

Land-cover Change Mapper (LCM), developed at the University of Calgary, is just such a tool. LCM rapidly generates a polygon vector layer (shapefiles) of change that can subsequently be refined by the interpreter. The interpreter can then remove, correct, or leave unedited, the output polygons. This tool is an implementation of a simple but innovative object-based approach to image differencing and threshold detection. In principle, it can be used to monitor any kind of extensive changes (at the spatial resolution of the imagery) involving a complete disappearance of the original land-cover. The most obvious examples include landscape changes created by forest fires and logging.

LCM was tested on Vancouver Island in an effort to demonstrate its accuracy and effectiveness in the monitoring of timber harvesting, an activity that generates 40 billion dollars per year in Canada.

The study area was a 20 km by 50 km rectangle. On southern Vancouver Island, that includes part of the Pelham and Somerset Ranges (with elevations up to 2,000 m), and roughly bound by the Port Alberni Inlet to the northwest and Nitnat Lake to the southeast (Figure 1).
Satellite images and reference data

The imagery used in this study comes from two B.C. government SPOT 5 (Satellite Pour l’Observation de la Terre) ortho-mosaics corresponding respectively to the years 2004 and 2006. The 2004 ortho-mosaic is composed of 2.5 m (pixel size) SPOT panchromatic imagery acquired between June and October 2004. The 2006 ortho-mosaic is a 5.0 m color infrared image derived from the fusion of the SPOT panchromatic and multispectral images acquired between June and September 2006. The two mosaics were clipped to the shape of the study area. The clipped 2004 mosaic was re-sampled to 5.0 m using pixel averaging. Only band 2 (red) of the clipped 2006 mosaic was used, since its histogram most resembled that of the single band 2004 mosaic.

The result is two grey-level 40 Megapixels images (4,000 columns X 10,000 rows) of 5.0 m pixel size, hereafter called the 2004 image and the 2006 image, or generically the initial-state image and the final-state image.

A reference (control) dataset was created by a geomatics company who mapped cutblocks that were harvested between 2004 and 2006 in Vancouver Island. They manually digitized on screen new cut-blocks based on visual interpretation of the same SPOT mosaics. The delivered product was externally audited and was found to comply with the high quality standards required for the project (Figure 2). The resulting vector layer, hereafter called the “interpreter layer” or “the human layer”, has 166 cut-blocks totalling 2,364 ha and 439 km of outlines.

Methods

In practice, when two images are co-registered it is unlikely that the footprint of two coincident pixels are identical. Errors may result from different satellite look angles and subsequent geometric distortions, by atmospheric interference, sun elevation angles and erratic variations in platform attitude. An image differencing algorithm that looks at the neighbourhood of pixels will tend to outperform one that does not. The LCM analyzes two co-registered images by determining that a given pixel in the first image whose footprint overlaps the most with a given pixel of the second
image is the neighbouring pixel in question, virtually removing the problem of spurious change due to misregistration. Once the difference image is produced, LCM proceeds through a workflow consisting of change mapping in the difference image (determining based on difference thresholds what actually constitutes a change), combining changes into logical regions (above a predetermined minimum map size), and the vectorization (outlining) of regions into polygons. The results are saved as a shapefile and associated database that can be viewed in the GIS environment. Though customizable, LCM operates as a fully unsupervised tool. Details of the methodology are given in Castilla et al., 2009.

Figure 3. Sample results. Left Panel: multi-temporal composite ([RGB] = [Difference, 2006, 2004]) of the 20 km × 50 km study area. New cut-blocks appear yellow. Right Panel: eight sample 2 km × 2 km sites with new cut-blocks labelled (a) through (h), correspond to the small white squares in the left panel image. Within the small images, LCM outlines are displayed as a black continuous line, and the photo-interpreter outlines as a dashed red line.
Table 1. Results of the LCM compared to a human interpreter.

<table>
<thead>
<tr>
<th></th>
<th>True Cut-blocks</th>
<th>False Cut-blocks</th>
<th>Undetected Cut-blocks</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>n</td>
<td>size (ha)</td>
<td>perimeter length (m)</td>
</tr>
<tr>
<td>Human</td>
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<td>14.19</td>
<td>2389</td>
</tr>
<tr>
<td>LCM$_{corr}$</td>
<td>185</td>
<td>12.68</td>
<td>2279</td>
</tr>
<tr>
<td>LCM</td>
<td>188</td>
<td>11.92</td>
<td>2260</td>
</tr>
</tbody>
</table>

Results

The results of the LCM interpreted layer were compared to the human interpreted layer (Table 1) showing the number, mean size and mean perimeter length of actual cut-blocks found, false cut-blocks reported, and cut-blocks undetected of each. The general degree of coincidence is excellent.

The full LCM process, from the initial- and final-state images to the polygon vector layer, took 96 seconds to complete on a typical desktop computer; less than three seconds per Megapixel or faster than any current commercial tool. Furthermore, most tools require some degree of user interaction and supervision during the processing, whereas with LCM the output vector layer is just one click away from the input images.

LCM detected 242 new cut-blocks (2,481 ha), of which 53 (238 ha) are false positives. The latter mainly correspond to old cut-blocks that appear darker in 2004 than in 2006. In many cases this was due to a cloud shading the area in the 2004 image (e.g., Figure 1a and 1b). LCM did miss five small cut-blocks totalling 7 ha that were probably removed because their LCM delineation was smaller than the MMU. In terms of area, the overall accuracy of the tool was 87 percent, with 301 ha of errors of omission and 426 ha of errors of commission, respectively 13 percent and 18 percent of the 2,364 ha reported as new cut-blocks by the interpreter.

A corrected layer was created (LCM$_{corr}$) with the notion that LCM could be incorporated into an operational assessment that allowed an interpreter to use the LCM vector layer as an initial template that was subsequently inspected and corrected where necessary. The subsequent hybrid layer was created in the GIS environment.

Based on statistics derived from the B.C. government contract within which the reference layer was produced, we estimate that an experienced analyst can find and digitize about 220 ha of cut-blocks per hour at an average digitization scale of 1:5,000 in the intensively harvested B.C. coastal forests. This translates to approximately 40 km of line work at the 1:1 scale per hour. Considering that the interpreter’s layer contains 439 km of outlines, it would take about 10 hours to complete a project of this scale. In contrast, the corrected LCM layer contains only 36.61 km of manually- delineated outlines out of a total of 424 km. That is, more than 90 percent of the total length of this final product comes from the automated delineation, which was created in less than two minutes.

The approximately 37 km of additional line work could have been delineated by an experienced interpreter in around an hour, to which it must be added the time required to perform the drag and click merging operations that remove both false
positives and the spurious polygons created along the manually digitized portions of outlines. The GIS union of the LCM layer with the manually corrected one has 477 polygons, whereas the latter has 312 polygons (holes included), meaning that 165 merges were performed. Allocating a generous 10 seconds per merging operation (note for example, that many of the merges can be performed simultaneously), this represents half an hour. Overall, the mapping of new cut-blocks in the study area could have been completed in one and a half hours instead of ten hours by using the LCM layer.

Conclusions

The Land-cover Change Mapper (LCM) is an automated tool that rapidly (<3 secs/Mpixel) generates a polygon shapefile with regions of change between two co-registered single or multi-channel remote sensing images. Required user defined parameters in a typical application are minimal, often only the size of the minimum mapping unit (MMU).

Despite being fully unsupervised, LCM achieved better accuracy than a user-intensive procedure based on commercial software, and provided high quality outlines enabling full integration with vector-based GIS.

Where the LCM layer is used as a base layer to manual interpretation, more than 90 percent of the outlines in the final product came from LCM automated delineation, which translated into a six-fold time saving compared to the human interpreter alone.

The time savings generated by using LCM can be extrapolated to other situations akin to clearcutting where the disturbances to be monitored involve clear changes in radiometry between the initial and final-state images, such as forest fires, tropical deforestation, glacier retreat, and any other extensive change involving a complete disappearance of the original land-cover. However, we anticipate that for linear features that have a few pixels width at the resolution of the imagery (e.g., roads, landslides, etc.), or when the changes in land-cover are partial (e.g., insect outbreaks, selective cutting, etc.), results may not be optimal, an issue that we will investigate in future research. Finally, we would like to note that LCM can also be easily used for multi-temporal change analysis by applying it sequentially to consecutive pairs of images in the time stack.

LCM is downloadable for free from the internet (http://sites.google.com/site/gastilla-tools/lcm).

References


More information:

For more information on LCM, contact Guillermo Castilla at gcastill@ucalgary.ca.

There is still time to register for River Restoration Northwest, a conference that focuses on stream restoration questions of concern to project planners, designers, engineers, biologists, hydrologists, geomorphologists, regulators, and land managers.

The intent of the Symposium is to highlight multi-disciplinary approaches to stream restoration design. For further information on the Symposium please visit the RRNW website at http://rrnw.org or contact Rob Sampson at: Rob.Sampson@id.usda.gov
Introducing:

Jillian Kelly is the Ground Water Protection Officer for the Vancouver Island Region, with the Water Stewardship Division of the Ministry of Environment. Jillian is responsible for maintaining positive, healthy working relationships with industry, other levels of government and the public with regards to well construction and groundwater use. She is also involved with groundwater studies and compliance and enforcement of the groundwater portion of the Water Act and the Ground Water Protection Regulation.

She is currently working on a salt water intrusion study and the compilation of a geochemistry study, both in the Gulf Island area.

Jillian completed a degree in Environmental Science at Royal Roads University and holds a technical diploma in Environmental Protection Technology from Kwantlen University in Richmond, BC. Prior to joining the Ministry of Environment in 2008, Jillian was involved in the private sector, specifically with contaminated sites.

In her spare time Jillian can be found exploring the diverse outdoor environment the Island offers with her partner Chris, and their dog Baden. Jillian can be contacted at (250) 751-3265 or by email at Jillian.Kelly@gov.bc.ca

Errata

Figure 5A in the previous issue (Debris flows and sediment recharge in gullies) was attributed to Glade 2005, neglecting the original version by Bovis and Jakob in 1999 (Bovis, M.J. and Jakob, M. 1999. The role of debris supply conditions in predicting debris flow activity. Earth Surface Processes and Landforms, 24(11):1039-1054.) The online version has since been corrected.

New Publications:


Upcoming issues:

Controls to landslide runout: How far will it go?

If you have topics that you would like to see in Island Geoscience, drop me a line at richard.guthrie@gov.bc.ca. In the meantime, thanks for reading and enjoy your fall!

- RHG