DIFFERENTIAL APPROACH FOR MAP REVISION FROM NEW MULTI-RESOLUTION SATELLITE IMAGERY AND EXISTING TOPOGRAPHIC DATA

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ABSTRACT

The Centre for Topographic Information (CTI), Geomatics Canada, NRCan is responsible for the National Topographic Database (NTDB) and the National Topographic Series (NTS) Maps at scales 1:50000 and 1:250000. One of the major tasks is the updating of the topographic information and the map revision operations. This paper addresses two aspects of revision. In the first one, a differential approach is proposed where emphasis is put into detecting the changes and integrating these changes with the existing topographic data to generate the updated maps, leaving untouched the unchanged cartographic data. In the second, the existing topographic data is used as ' a-priori knowledge' to facilitate change detection, extraction, and validation using multi-resolution satellite imagery. The Indian Remote Sensing satellite images (IRS) from both the 5.8m high resolution PAN and the 23.5m medium resolution LISS 3 sensors were fused and integrated with the existing topographic vectors, vegetation in this case, for a semi-automatic updating process. The paper discusses the methodology and the initial results obtained and demonstrates the potential of the approach for rapid map revision operations.

1 INTRODUCTION

The Centre for Topographic Information (CTI), Geomatics Canada, NRCan is responsible for the National Topographic Database (NTDB) and the National Topographic Series (NTS) Maps at scales 1:50000 and 1:250000. As we started moving from the database creation operations to database updating and maintenance, one of the major tasks is the updating of the topographic information and the map revision operations. Under these conditions an investigation is under way to study and implement a process for the rapid updating of the topographic maps.

Presently, the map updating and revision process is based on a data holistic approach where for each new map all topographic data are collected in vector form, symbolized and validated. The proposed methodology is based on a differential integrated map raster and vector approach where the changes are detected, collected in vector form and integrated to the existing vector/raster cartographic theme layers. To compliment the topographic layers from the NTDB and other sources in meeting the NTS maps specifications work has been carried out in the use of imagery for change detection and data updating operations. For revision of planimetry, the Centre for Topographic Information (CTI) has utilized digital orthoimages from aerial photography (Armenakis et al., 1995; Armenakis and Regan, 1996) and SPOT panchromatic imagery (Savopol, 1994) for updating of the National Topographic Database (NTDB) and NTS maps in a monoscopic mode. The work continued with the evaluation of the mapping potential of the IRS-1C PAN imagery (Armenakis and Savopol, 1998).

In this paper we expand on the use of multi-resolution panchromatic and multi-spectral satellite images for change detection, extraction, classification, and most important for validation of contract work. Existing topographic data are used as " a priori cartographic knowledge" to support the planimetric revision operations. Revision of hypsography from satellite sensors is also a very important operation for CTI, where stereo or InSAR modes are considered for evaluation at another phase of this project.

2 METHODOLOGY

The objective is to develop and implement an approach for rapid map revision. In this context a differential/incremental mode of updating the NTS maps is being put into place. That is, the updating and revision (including symbolization,

validation) applies only on the cartographic elements that have changed from the previous map edition. The process flow is shown in Figure 1.
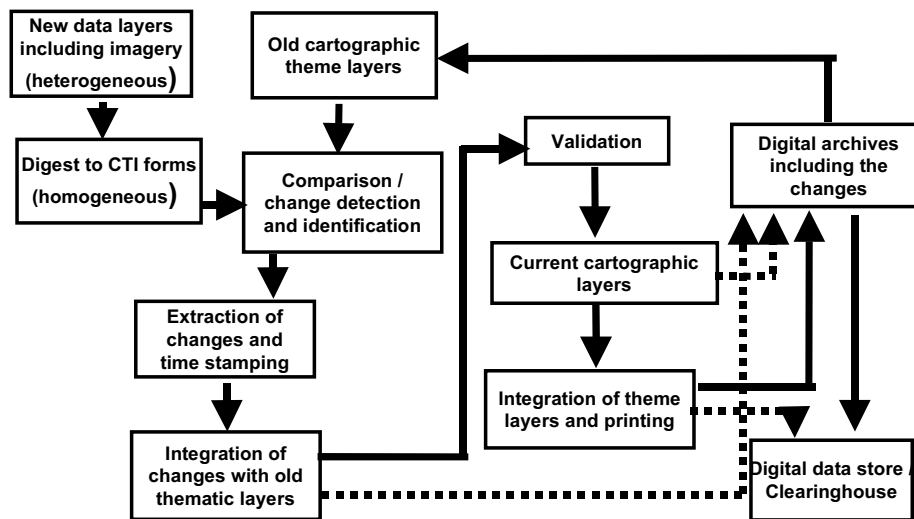

Figure 1:Differential updating mode for the revision of topographic data.

Considering the impact of the high resolution satellite imagery in the mapping applications and the high cost of aerial photography, and based on the successful use of satellite imagery by CTI as mentioned earlier, satellite imagery was the source of the new data for the updating. To introduce a form of automation in the process of change detection, classification and extraction from new image data two aspects were considered. The meeting of geometric accuracy requirements and the selection of an automated image segmentation process. High resolution satellite imagery satisfies the geometric requirements, while medium to low multi-spectral satellite imagery can be used with classification algorithms to facilitate the segmentation process. However, the results (e.g., boundaries of polygons) of an automated classification applied to the multi-spectral imagery will not satisfy the positional accuracy required. One option could be to extract boundaries from the high resolution panchromatic imagery and based on these boundary edges adjust the edges of the lower resolution multi-spectral imagery (Heipke and Straub, 1999). The other alternative, which was applied here, was the fusion of the panchromatic and multi-spectral image data through and Intensity-Hue-Saturation (IHS) transformation (Lillesand and Kiefer, 1987), which supports the display of spatially georeferenced images of different ground resolution. The IHS transformation reduces the band spectrum of the multi-spectral image, however in our case as we will see from our available data we had three channels to start with in the multi-spectra imagery and we have quite distinct land cover classes. By applying the IHS transformation to the low resolution it is possible to replace the Intensity channel with the high resolution panchromatic channel, while the low resolution channels are displayed as the Hue and Saturation channels. The result is a high resolution RGB image, where supervised classification can be applied. The ' a-priori knowledge' of the existing cartographic data was introduced at this stage to facilitate the selection of the training areas. The results of the classification defining the new updated polygonal areas can now be compared with the existing vector/raster cartographic data and through either visual inspection or by Boolean operations the changes can be determined and integrated, thus updating the existing cartographic data sets.

3   DATA AND SYSTEMS

The test area was located just east of Montreal, Canada covering the 1:50 000 NTS map 31H06 and its size is 30' x15' (about 39km x 27km). The new data source was the IRS 1C PAN and LISS 3 satellite images acquired on 12 May 1999 Path 289 and Row 037. The PAN sensor provides panchromatic data (0.5-0.75μm) with ground resolution of 5.8m and 6-bit quantization and covers 70km x 70k. The LISS 3 (Linear Imaging Self Scanning) multi-spectral sensor provides three channels (channel 1: 0.52-0.59 μm (green); channel 2: 0.62-0.68 μm (red); channel 3: 0.77-0.86 μm (NIR)) with ground resolution of 23.5m, and one channel (channel 4: 1.550-1.7000 μm (short wave IR) with ground resolution of 70.5m and covers about 142km x142km, with all channels having 7-bit quantization. Both images were delivered path oriented, 5m and 20m, and 8-bit.

The horizontal coordinates of control points for the ortho-rectification of the satellite images were collected from digital ortho-photos having ground resolution of 2m. The control points for the ortho-photos were provided by the Aerial Survey Database (ASDB). The height of the control points was extracted from the 25m grid DEM generated automatically for the creation of the ortho-photos. The accuracy of the control points is under 2m. The DEM required for the ortho-recification of the satellite images was generated from the 1:50 000 NTDB contours at 50m grid interval. The existing ' old' topographic and cartographic data were provided by the NTDB and the Cartographic Editing System (CES).

The systems used were the PCI by PCI Geomatics for the orthorectification of the satellite images, the IHS transformation and the supervised classification; the LH Systems digital scanning and photogrammetric workstations for the production of the ortho-photos; and the CARIS by Universal Systems for the cartographic production and for providing the cartographic themes.

4   RESULTS

Both the PAN and LISS 3 images were ortho-rectified using clusters of control points measured derived from the ortho-photos (Fig. 2 and 3). The use of digital ortho-photos has the advantage to easily select large numbers of point features identifiable on both images within the area of the ortho-photo mega-chips (about 6km x10km). The sensor model was estimated based on the collinearity equations (Toutin and Carbonneau, 1989). For the PAN image, the X and Y RMS of the residual errors at the control points were 3.32m and 3.75m, respectively. The X, Y RMS residual errors for the worst 5% of control points were 7.45m and 6.97m. In total 52 points were used (about 6-7 points per ortho-photo). When some of these points were used as check points the RMS errors were in the 5m range. Respectively, for the LISS 3 image, the X and Y RMS of the residual errors at the control points were 5.18m and 4.18m, respectively. The X, Y RMS residual errors for the worst 5% of control points were 5.51m and 11.46m. In total 38 points were used (about 5-6 points per ortho-photo). When some of these points were used as check points the RMS errors were in the 10m range.

The parts of both images covering the map area were resampled to 5m ground resolution using the cubic convolution algorithm and the 50m DEM. It is necessary to have the same resolution for the application of the data fusion. For the IHS transformation (RGB to IHS and vice versa) the single-hexcone colour model was used (Foley et al., 1990).
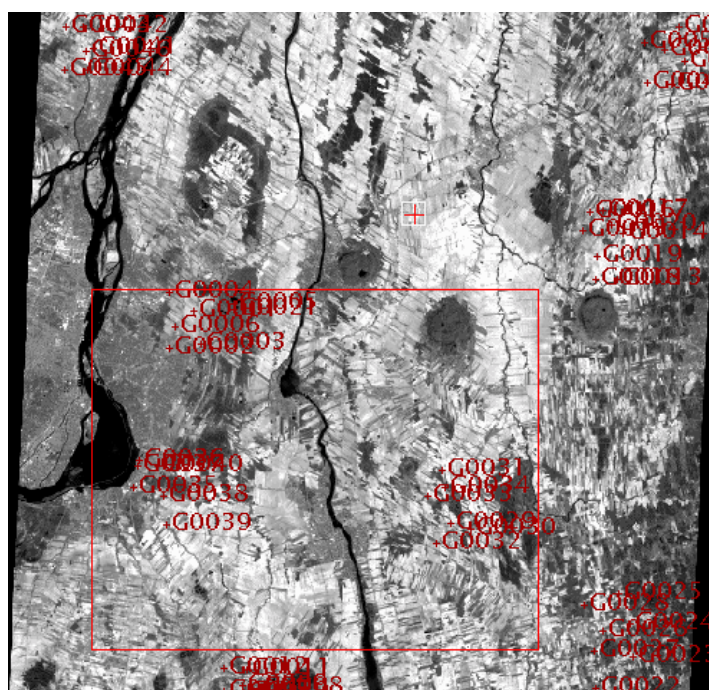

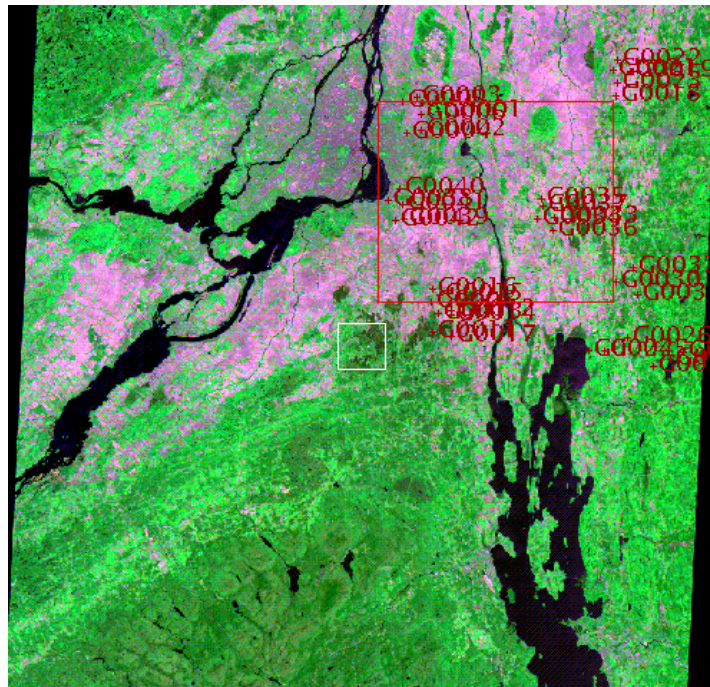Figure 2: Distribution of the clusters of control point in the PAN imagery.

Figure 3: Distribution of the clusters of control point in the LISS 3 imagery.

For this initial demonstration of this approach the vegetation theme was selected. The existing cartographic vegetation data were superimposed on the high resolution RGB imagery. Based on this vegetation information several training areas were selected followed by a supervised classification using the maximum likelihood classifier over the entire image. Using only the vegetation theme the accuracy of the classifier obtained based on the training areas was 96.27%. The old and new vegetation areas were superimposed and the differences are easy to detect and quite visible (Fig.4a and 4b). Further, these classified areas have to be verified, aggregated and smoothed so through interactive or Boolean operations changes can be determined and the corresponding cartographic themes be updated using only the changes.
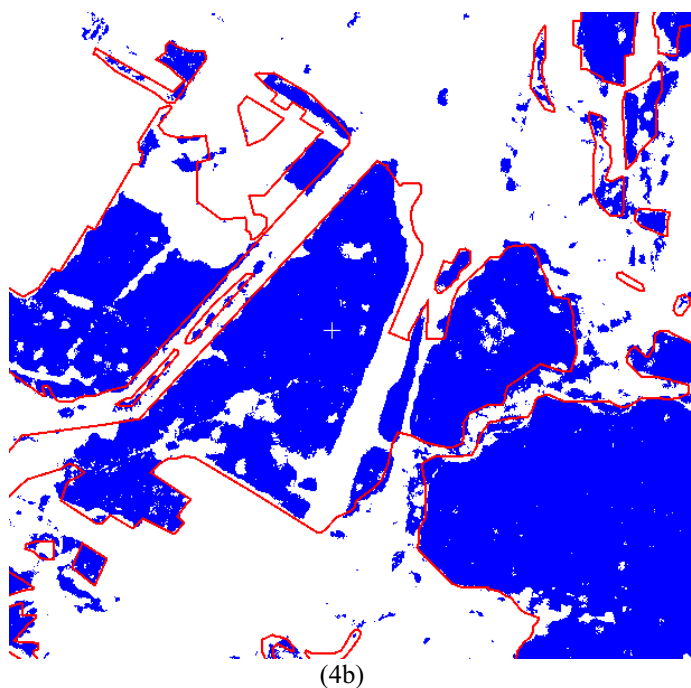

(4a)

(4b)
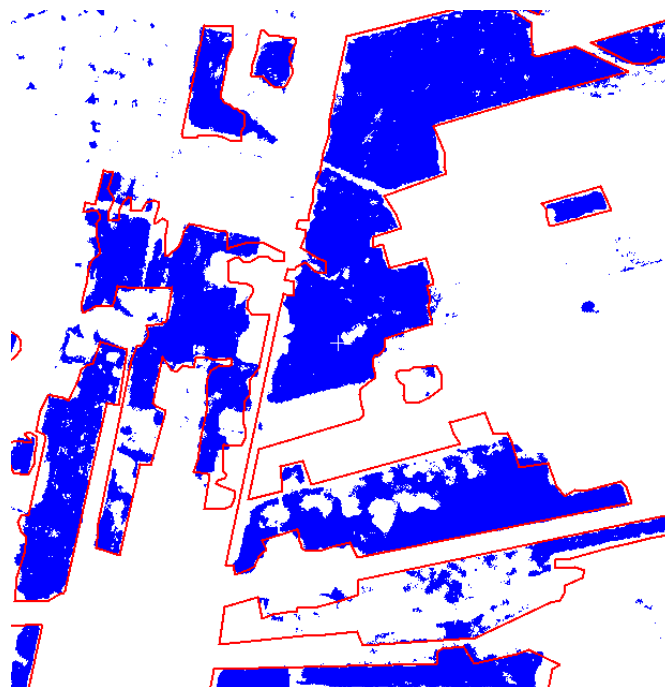
Figure 4: Old and new (unedited) areas of the vegetation theme.

5   CONLUSIONS

In an effort to develop and implement a rapid revision system for map production, this work concentrated into two areas. The reduction of effort from working on the entire data sets for each revision cycle and in the use of semi-automated processes. The differential mode concentrates the revision and mapping operations in to areas where changes occurred. The fusion of high and medium spatial resolution satellite imagery supported with existing topographic data and automated classification methods proved to be successful for this pilot project. Additional work is required to further test this approach with more cartographic layers and to implement it in the production process. Experience gained through this prototype project will be used to improve in-house work and validation procedures as it is anticipated that most of the map revision work will be carried out by industry.

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