CHANGE DETECTION AND EXTRACTION
BETWEEN RASTER MAPS AND LANDSAT 7 IMAGERY

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KEY WORDS: Change detection, Landsat 7 imagery, scanned maps, feature extraction, national topographic databases, revision.

ABSTRACT

Database updating and maintenance is becoming a more and more frequent operation in national mapping organisations. Major tasks are the change detection and extraction and its integration in the existing data sets. Change detection is performed between a number of data sets involved in topographic applications. In our study, the two data sets are monochrome rasterized paper maps of areas in Northern Canada at time t_1 and Landsat 7 ETM+ imagery at time t_2. These were used for the determination of planimetric changes. Prior to change detection, extraction of features from both the rasterized maps and the Landsat 7 imagery is necessary. Texture measures and thresholding approaches were used to evaluate the potential of rapid extraction of map elements. The extraction of features from the imagery involved initially image and theme enhancement by applying various image fusion (e.g., IHS, Brovey, PCA, PCI-IMGFUSE) and spectral enhancement (e.g., Tasselled Cap, NDVI) approaches, followed by image thresholding and classification. Having defined the domain of comparison, change detection was performed both visually and in an automated mode based on buffer zone generation and on the non-intersection of old and new features. The various approaches and methodology developed and implemented along with examples, initial results and limitations are presented and discussed.

1   INTRODUCTION

Moving from database populating operations to database updating and maintenance is becoming a more and more frequent operation in national mapping organisations. Major tasks are the change detection, change extraction and change integration in the existing datasets. The upcoming plethora of high spatial and spectral resolution satellite imagery along with its high frequency multi-temporal nature will increase the pressure for shorter updating cycles and rapid revision operations. Therefore the increase in automation for change detection, classification and extraction from current data sources, and the integration of changes with the existing geo-spatial databases is quite desirable.

Due to the size of the Canadian territory, current operations at the Centre for Topographic Information, Mapping Services Branch, NRCan, involve the planimetric updating of certain features (such as the road network) in cooperation with the provincial mapping agencies, while other planimetric features would be updated from satellite imagery. Medium/low resolution satellite imagery such as the IRS PAN and LISS has been used (Armenakis and Savopol, 1998; Armenakis, 2000). Due to higher cost and copyright restrictions involved, the image layer of the national framework data will now consist of the 15m and 30m resolutions of Landsat 7 ortho-images (panchromatic and multispectral) for the entire country.

In this paper we will address issues dealing with the change detection and updating process and give examples of change detection operations between scanned rasterized maps (in areas where not digital data exist), and new imagery. We will present and discuss the various updating scenarios using Landsat-7 satellite imagery as the new data sources, while the old datasets to be revised are 1:50K scanned monochrome topographic maps. Detected changes will be used to update the national topographic vector database. The various approaches, methodology including the potential of digital image processing techniques and the initial results obtained will be presented and discussed.

2   CHANGE DETECTION ANALYSIS

Change detection analysis can be defined as the identification and location of differences in the patterns of two temporal datasets at times t_1 and t_2. Specifically change detection involves the comparison of two datasets and consists of four processes, a) detection, that is the discovery of change, b) recognition, that is the thematic classification of the change, c) identification, that is the description of the feature of the thematic change and d) quantification, that is the measure of the magnitude of changes.

Since there is a number of types of datasets involved in topographic applications, change detection may be required to be performed between image and vector data, between image and image data, between image and map data, between vector and vector data, and between map and map data. Change detection between two multidated images can be digitally performed and has reached operational level (Singh, 1989; Hayes and Sader, 2001). However, change detection between other type of data such as current imagery and old topographic data is mostly done visually, while certain level of automation has been recently introduced (Heipke and Straub, 1999; Ohlhof et al.; 2000; Armenakis, 2000). When comparing two datasets the domain of comparison has to be defined. For example, vector data provides a classified abstract representation of the landscape, while imagery is a unclassified continuous but resolution-dependent generalized representation of the landscape. If comparing data of the same nature (i.e., two homogeneous satellite images) the change detection can be computed at the *data level* domain (comparison of pre-processed data), while when comparing heterogeneous datasets the change detection is performed at the *decision level* domain (comparison of analysed data), as some data processing (e.g., image classification, vectorization of detected features) needs to be done prior to change detection.

In our study, the two datasets are monochrome paper maps of areas in Northern Canada at time t_1 and Landsat 7 ETM+ imagery at time t_2. As the changes will be used to update a vector-based database, the differentials between old and new data are to be determined mainly in the vector domain and at the decision level. Therefore, the objectives are to extract features in vector form from both the map and the Landsat 7 imagery and have the comparison performed at the decision level using either the imagery or the raster map as reference background.

Fully automated vectorization of the raster map at this phase would be rather difficult as it would require the development and implementation of pattern recognition techniques for symbol identification and extraction of various cartographically represented elements, which presently cannot automatically be distinguished without human intervention. In this case study, a semi-automated approach for feature extraction is the computer-assisted vectorization (e.g., on-screen line follower) of the rasterized map elements. Fast vectorization of map elements was also done by texture analysis and thresholding followed by raster-to-vector conversion without any topology. For the Landsat 7 imagery vectorization, the boundaries of polygonal features were extracted after the classification process. Detection of changes can then be performed either visually in an interactive mode or digitally in an automatic mode. In the visual mode, either the vector data from the map are superimposed on the Landsat 7 imagery supported as well from the classified image regions or the classified image regions (and/or their boundaries) are superimposed on the monochrome raster map. In the digital mode, the geometric changes are determined in an automated mode. A buffer is created around the old data of a theme based on the accuracy tolerance limits. Whatever vector segments are outside this buffer are considered as addition/modification. A buffer is also generated around the new vector data. Whatever, vector segments are outside this buffer are considered as deletion/modification. Modifications occur if changes apply to an object of the theme. In the raster environment, changes are determined by simply substracting the two datasets.

The changes in the data patterns are then determined based on the following definitions:
Confirmation of the existing data, when neither their spatial nor the attribute elements of an existing feature have changed.
Addition of features, when a totally new feature is added.
Deletion of feature when a feature is totally eliminated.
Modification of features, when either the spatial and/or the attribute characteristics of an existing feature have changed. Modification can therefore be in the forms of:
a) *Spatial modification*, when the changes in the geometry of an existing feature and its corresponding new feature exceed the tolerance buffer limits and/or when the topology changes; and
b) *Attribute modification*, when the thematic values of an existing feature change.

The information about deletions, additions and modification should be kept and time stamped in separate files, thus facilitating the tracking of the changes. For the integration of the new and old datasets, validation and editing including topology are required.

3   FEATURE EXTRACTION

3.1   Extraction from scanned maps

The extraction of certain features from rasterized (via scanning) monochromes maps for automated process was tested with various image analysis methods, such as texture analysis (section 3.1.1) and thresholding (section 3.1.2)

3.1.1   Texture analysis

Texture measures have been studied about two decades ago (Haralick, 1979). Texture can simply be defined as the analysis of grey level variations in a pixel's neighbourhood. This grey level variation can be directional or not. Texture measures can be expressed in terms of variance, mean, entropy, energy, homogeneity, etc.

Based on these measures, a method has been developed to automate the vectorization of lakes from the scanned maps. This automated vectorization is limited to the extraction of lakes that appear, in the 1:50 000 scale monochrome maps, in polygonal screened grey pattern while the rest of the map is represented by linear pattern (Figure 1). The right part shows two elements of the 1:50 000 scale map originally scanned at 600 dpi resolution.
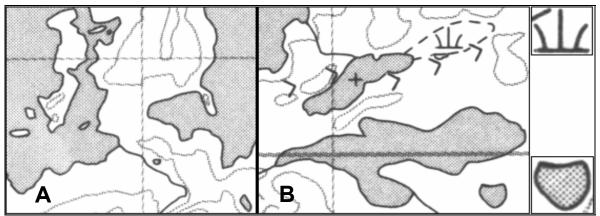

Figure 1– Appearance of lakes on a 1:50 000 scale monochrome map. A-B: two different zones showing lakes (in grey).
Right: some elements of B at the original scanning resolution (600 dpi).

In this experiment, the following parameters have been tested for cartographic patterns such as screened lake fills: mean, entropy and variance. Preliminary results have shown that the entropy parameter was the most promising. The entropy measure of texture analysis, where certain the cartographic patterns of certain polygonal elements are extracted based on the relative degree of randomness of their pattern is defined as

$$\text{Entropy} = \sum P_{\alpha,d}(a,b)\log P_{\alpha,d}(a,b) \tag{1}$$

where P is the co-occurrence matrix, describing how frequently two pixels with grey values a, b appear in a window separated by distance d in direction α (Sonka et al., 1993). In our experiment, we used a distance of 1 between two neighbouring pixels and a directional invariant outcome. The degree of detection of small objects depends on the kernel size of co-occurrence matrix of the entropy measure (11x11 pixels kernel was used). Larger size kernel allows for more data to compute a significant entropy measure but reduces the ability to detect small objects.

The steps to automatically extract the lake boundaries are: 1) apply a texture filter to the raster map, 2) threshold the resulting image between lakes and no lakes, 3) apply a median filter to eliminate noise and 4) vectorize the binary image obtained in 3. Vectors resulting from this method are shown in Figure 2.
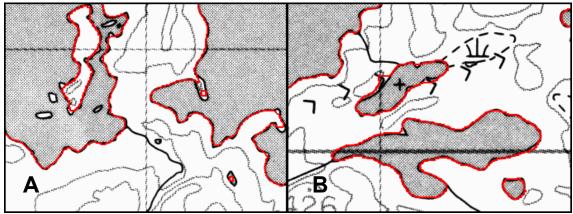
Figure 2 – Examples of lake extraction from scanned map using entropy measure (zones A and B).

3.1.2   Thresholding

The map thresholding is defined as following, where certain elements of the map $F_m(x,y)$ are extracted from the monochrome raster map image $R_m(x,y)$ based on a thresholding interval of grey values g_i and g_j:

$$F_m(x,y) = \begin{cases} 1 \text{ for } g_i < R_m(x,y) < g_j \\ 0 \text{ for } R_m(x,y) < g_i \text{ and } R_m(x,y) > g_j \end{cases} \quad (2)$$

It was observed that the map thresholding permits to distinguish, in a raster format, relevant topographic information such as the lakes, rivers, wetlands, wooded areas, eskers, roads, etc. from contours and grid lines. This method uses the fact that the map lines which delineate or represent most of the cartographic information (including symbols and toponymy) appear much darker than contours and grid lines. The most appropriate threshold value g_j (considering $g_i=0$) has to be determined by the operator since this value may vary according to the printing and scanning specifics. The result of the map thresholding is then filtered (median and sieve, the latter remove all polygons smaller than a given minimum size, measured in pixels area) to remove noise. The level of filtering must be chosen adequately to both keep small or isolated feature map lines and remove enough grid lines and contours that may reduce the feature visibility.

In the case where vector features are required for the change detection process, a fast R-V conversion or a manual/interactive vectorization of thresholded results could be applied. From the fast vectorization, we obtain double-line vectors of raster elements that represent map content (including all features in one layer). These vectors are used mainly for visual interpretation of change detection with the satellite image as background (see section 4.1). The limited use of these output vectors is explained by the fact that they are not in the appropriate format (to consider them as vectors, manual edition has to be done in a time-consuming process) and also these vectors include topographic features as well as symbols and text. An example of these double-line vectors is presented in Figure 3.
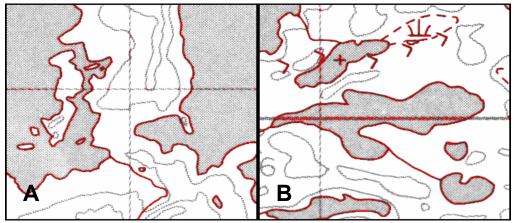

Figure 3 - Examples of lake extraction from scanned map using thresholding method (zones A and B).

If we compare results obtained by the texture (Figure 2) and by the thresholding/filtering (Figure 3) approaches, the texture-based lake extraction process permits the quick vectorisation of the general shape of lakes, but it also imposes some limitations in the detection of small islands or lakes, narrow water passages or peninsulas but also in the delineation of feature shape. In the case of map thresholding, the result contains more information as rivers, marshes, eskers, etc. and represents more accurately and in more detail the map content. On the other hand, the thresholding output is in raster format and the proper vectorisation process, if needed, requires a kind of interactive/manual process that is costly time-consuming compared to the texture-based lake extraction. Figure 4 shows the comparison between the automatic vectorization (from texture analysis) and the interactive/manual vectorization for lakes extraction.
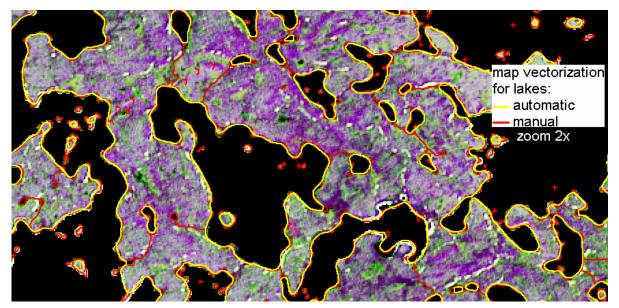

Figure 4 – Extraction of lakes from two methods (vector outputs). Yellow: lakes extracted automatically (from texture analysis). Red: lakes extracted interactively/manually.

3.2 Feature extraction from the Landsat-7 image

Landsat-7 imagery, by its ground resolution, is limited in its capacity of detection/extraction of 1:50K scale map features. Some features, extracted from scanned map (see section 3.1), are not visible or not distinguishable in the image. Regarding the geographic location, the topography of the terrain, and the type and number of topographic features to consider, the time of the year for image acquisition represents also an important limiting factor. To improve the capacity for feature distinction and interpretation from the Landsat-7, various image enhancement techniques (radiometric, spatial and spectral) are required prior to any feature extraction. Specifically for feature recognition, we have tested image fusion, Tasseled Cap and NDVI image transformations. Feature extraction was then performed by either thresholding or image classification followed by automatic vectorization if required.

3.2.1 Image Fusion

The image fusion implies the merging of the high resolution panchromatic band (ETM-8) with the low resolution multispectral bands. The aim of the fusion is to take advantage of both high resolution and multispectral content. The result of the fusion is an enhanced multispectral or synthetic imagery of the high resolution. Various methods for image fusion, such as IHS, PCA, band substitution, arithmetic and Brovey, were tested as to their enhancement potential of various features.

The IHS is the transformation of three multispectral channels into Intensity-Hue-Saturation (IHS) colour space. Afterwards, the intensity channel is replaced by the panchromatic band and the IHS image is converted back into red-green-blue (RGB) colour space. The arithmetic method is simply the addition of the panchromatic channel to each multispectral channels. Another way of using this additive method is to enhance the panchromatic band with a high-pass filter. The filtered panchromatic band is then added to the multispectral channels. Finally, the Brovey transform is the multiplication of a multispectral channel divided by the sum of all multispectral channels used by the panchromatic band as follow:

$$\mathbf{F_i = (M_i / \Sigma M_i) * P} \tag{3}$$

where F_i is a fused channel, M_i is the multispectral channel to be fused and P is the panchromatic band. ΣM_i is the summation of all multispectral channels (6 in our case).

The PCA method is another image fusion approach that decorrelates the data into fewer bands (called principal components) which contain the maximum intensity variance corresponding to main information that could be extracted (redundant data are then reduced). The PCA was applied here using 7 bands (6 multispectral and 1 panchromatic).

We used also the IMGFUSE routine of PCI that is based on cross-correlation between high and low resolution bands (computed band by band). The advantage of this fusion method is that it preserves the radiometric properties of the original multispectral channels (Cheng et al., 2000), while IHS and PCA usually distort them (Chavez et al., 1991). Its main inconvenience is that it results in local blurring display depending of the level of correlation.

Comparing the results of various image fusion techniques for Landsat-7, no significant difference was noticed between simple and more computationally intensive methods. Edge-sharpening filter (HPF) of panchromatic band generally improved the fusion results.

3.2.2 Spectral Transformations

One of our test region is located in a northern region of Alberta, Canada (centered on 115°45'W and 57°37'N), in a zone characterised by important vegetation coverage (mixed boreal forest). As the vegetation cover seems to be an important factor modulating the information content of the various Landsat-7 bands (acquired on May 29, 2000), a spectral band transformation expressly designed for the enhancement of the vegetation cover density and condition, called the "Tasselled Cap" (Mather, 1987), was applied. The 6 multispectral bands of Landsat-7 except the thermal ones are used in order to compute three parameters called brightness, greenness and wetness. Brightness is a weighted sum of all 6 ETM channels and expresses the total reflection capacity of a surface cover. Small areas dominated by dispersed vegetation appear brighter (high total reflection). Greenness expresses the difference between the total reflectance in the near infrared bands and in the visible bands and has been shown to be moderately well correlate to the density of the vegetation cover. Wetness expresses the difference between the total reflection capacity between the visible-near infrared channels and the SWIR channels, more sensitive to moisture surface content.

Besides Tasseled Cap transformation, the NDVI (Normalized Difference Vegetation Index) was also calculated to enhance vegetation variations or changes appearing in the image:

$$\text{NDVI} = \frac{\text{ETM4} - \text{ETM3}}{\text{ETM4} + \text{ETM3}} \tag{4}$$

3.2.3 Feature extraction

Based on the geographic location, the land cover and the time of the year for image acquisition, the choice of feature extraction technique depends on the theme considered.

3.2.3.1 Thresholding

A Landsat-7 image was acquired on June 14, 2000 covering a taiga zone located in the North West Territories, Canada (centred on 111°15'W and 63°52'N). At this latitude and time of the year, most of the large lakes are still frozen. Within the smaller lakes, most of the covering ice was melted. The difference between frozen and unfrozen lakes with spectral band ETM1 to ETM4 was clearly visible. Spectral bands ETM5 and ETM7 did not show this distinction. This fact is important as we are not interested in this difference. Figure 5 give a visual comparison between band ETM-5 and bands ETM-345 with the overlay of map vectors.

Classifying the water with bands ETM1 to ETM4 and even with ETM8 (panchromatic) was difficult because of the difference between frozen and unfrozen water and even within the ice covers. Finally, a simple thresholding of band ETM5, considering values (grey levels) from 0 to 25, allowed us to extract all the lakes (Figure 5).

In all the fusion experiments, few feature improvements were obtained because of the nature of each spectral band and the time of acquisition of the image (frozen water, wet soils, few vegetation, etc). In this particular case, only lakes could be extracted by a simple thresholding (no fusion and supervised classification were necessary).
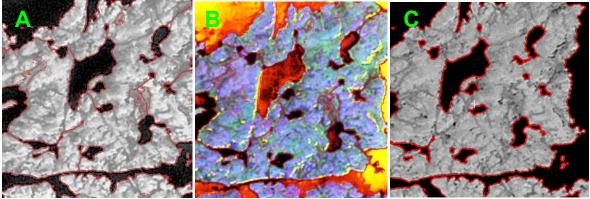

Figure 5 - Band ETM-5 (A) and ETM-345 (B) with map vectors obtained by thresholding (Red). Extraction of lakes from ETM-5 band (C) (vectors in red)

3.2.3.2   Classification

Noting that field ground truth and verification are not available, the existing geo-spatial databases are used as 'prior knowledge' to provide cues and guidance in the classification process from imagery. This knowledge is used as contextual information for selecting training sites for pixel-based classification.

For the classification process, we used as input data the three bands of the fused image (PCI-IMGFUSE routine) corresponding to ETM3, ETM4 and ETM5, the three Tasseled Cap parameters (brightness, greenness and wetness) and the NDVI result. The training sites were selected considering our prior knowledge of the topographic features that are scanned map vectors and 1981 fire polygons obtained from the Alberta Sustainable Resource Development, Forest Protection (Figure 6).
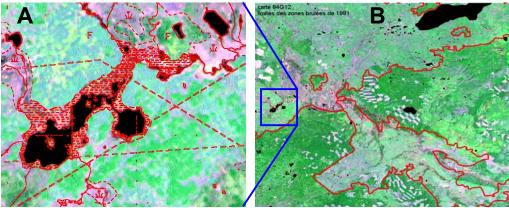

Figure 6 – Fused image ETM3-4-5 superimposed with map content vectors (A) and fire polygons (B) for selection of training sites.

Concerning certain features such as wetlands or wooded areas, the selection of training sites is somehow difficult due to the variation in spectral signatures for these features. These variations could reflect the presence of sub-classes in the defined topographic feature (e.g., cleared cuts, burned areas and regenerated forests are included in wooded areas, while all types and conditions of swamps/marshes are included in wetlands). To take into account these spectral variations even though there are not reflected in the map content, different training sites have to be selected to create several sub-classes for the same feature. After the classification process (by maximum of likelihood, see Figure 7 for the entire

classified image), sub-classes were aggregated to adapt the detected classes to general categories of map elements (vegetation, wetlands, water bodies). In this case, 6 sub-classes were extracted (water bodies, marshes, swamps, recent cuts, burned areas, wooded areas) and aggregated to obtain 3 final classes (water bodies, wetlands and vegetation). Based on our training sites, the Kappa coefficient was 0.95. In comparison, without image fusion, the classification leads to Kappa coefficient of 0.87.

Following supervised image classification, features detected and properly identified are then filtered to consider the minimal size requirements/specifications of the map. Then, the boundaries of the classified regions were subsequently vectorized. Tests for feature extraction from imagery have been limited to polygonal features.
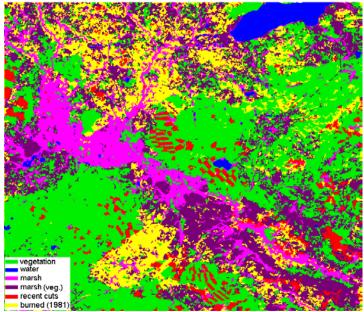

Figure 7 – Classified image

4   CHANGE DETECTION PROCEDURE

There are two ways of detecting changes between scanned map and Landsat-7 image, based on the feature extraction done previously (raster or vector outputs): visual (section 4.1) and automatic change detection (section 4.2). Changes could be detected and registered only in the case that the feature is visible and identifiable with no doubt on the Landsat-7 image. Planimetric accuracy tolerance is used for the acceptance or rejection of differences as actual changes. Regarding the type of changes, based on the contextual information confirmations and geometric modifications will be done with higher confidence than additions or deletions that imply a certain level of feature identification that is difficult to get from Landsat-7 only. These two types of changes have to be determined with caution in Landat-7 image due to its resolution. For example, a map feature will not have necessarily to be removed or added if it is not visible and properly identifiable in the image.

4.1   Visual change detection

The visual comparison between the scanned map and Landsat-7 image could be used in preparation/planning of map revision and/or validation of map changes where an overview of changes is needed. This visual change detection implies a general and quick evaluation of the type and magnitude of changes (quantification and localization of changes) between an old scanned map and a new Landsat-7 image currently acquired.
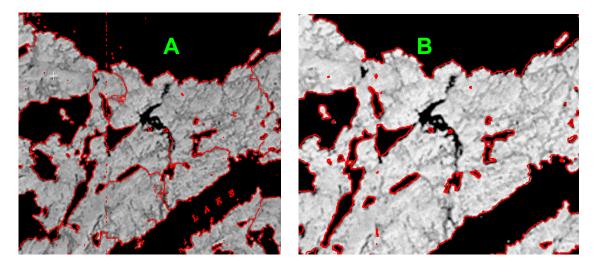
Figure 8 – Visual change detection with Landsat-7 band ETM5 as background. A) Map lake vectors obtained by thresholding and B) map lake vectors obtained by texture analysis.

This kind of process is done in two ways depending on the reference background data used for detection: 1) change detection based on extracted map vector elements superimposed on a RGB form of Landsat-7 image (Figure 8), and 2) change detection based on extracted features from the imagery superimposed with the raster map (Figure 9). Changes that are detected are either noted by the operator or registered on a new vector layer to support an automate quantification process. In examples of figures 8 and 9, some new lakes or lakes boundaries that have to be updated can be located and identified.
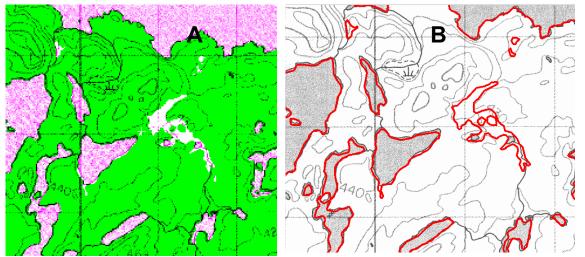

Figure 9 – Visual change detection with image features obtained by image classification. A) Colour composite containing lake polygons and the raster map as background; B) lake boundaries (in red) superimposed with raster map as background

4.2   Automatic change detection

Besides the visual change detection, automatic change detection is performed as well by computing differences between either vector data or raster data from both sources (map at time t_1 and image at time t_2).

4.2.1   Raster approach

Change detection using raster data could be processed automatically by subtracting two bitmap layers: one containing the feature class extracted from the Landsat-7 image and the second containing the same feature class extracted from the raster map (by thresholding the results of entropy measure). In our experiment, only lakes (water bodies) could be extracted automatically (in bitmap format) from the two datasets. Therefore, the change detection between raster data was limited to this particular feature. The result of subtracting the map layer from the image layer will permit to quickly locate and quantify (by pixel counting) the magnitude of geometric changes (positive value corresponds to addition differences and negative value to deletion differences). The geometric differences must satisfy the pre-defined accuracy tolerance to be considered as changes by applying appropriate spatial minimum size filter.

4.2.2   Vector approach

Change detection using vector data could be processed automatically in two ways:

1) Change detection by buffer generation, where a spatial buffer is created around both the old feature (vectors extracted from map) and new feature (vectors extracted from imagery). This buffer, based on the accuracy tolerance limits, is used to keep only significant changes and geometric inaccuracies. Whatever vector segments are outside this buffer are considered as changes: a) if the new elements from the imagery are outside the map feature buffer, changes are considered addition/modification; or b) if the old elements from the map are outside the image feature buffer, changes are considered deletion/modification (Figure 10). This approach can also provide immediate quantification of changes per theme by the total length of modified vector segments (add and delete vectors).
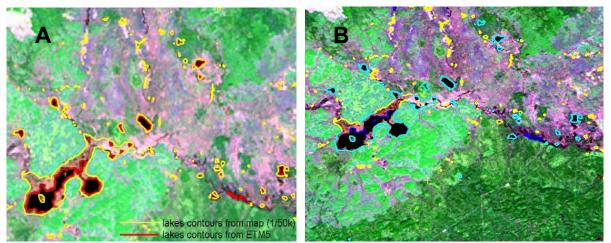

Figure 10 – Change detection by buffer generation (presented with fused image ETM-345 as background). A) Input lake vectors extracted from raster map (yellow) and imagery (red). B) Vector changes for lakes obtained automatically: confirmed existing vector segments (cyan), new vector segments to add (blue) and vector segments to remove (yellow).

2) Change detection by determining the non-intersection of the old and new features. Two types of non-intersections are given by this process: a) if the non-intersection contains map data as output only, changes are considered as deletion/modification; or b) if the non-intersection contains Landsat data as output only, changes are considered as addition/modification (Figure 11a). To apply the pre-defined tolerance level for changes, the non-intersection areas are then filtered (Figure 11b). This approach can also provide per theme immediate quantification of changes by summation of differences.
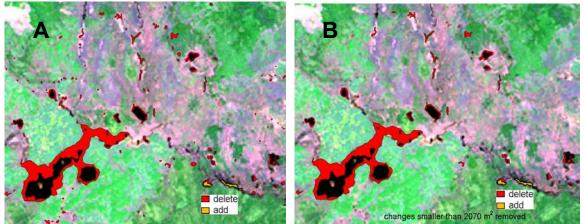
Figure 11 – Change detection by feature subtraction (presented with fused image ETM-345 as background). A) Polygonal differences for lakes obtained by subtracting map vectors and image vectors. B) Polygonal changes for lakes obtained by filtering polygonal differences of a) according to the tolerance (minimum area of 2070 m^2).

5   CONCLUSION

Rapid change detection and data updating is becoming a significant requirement for mapping organizations. Detecting and monitoring changes of the landscape supports also sustainable development. The data sets to be compared at two or more time periods could vary in nature and homogeneity. In our case the initial data set was monochrome raster maps, while the new data set was Landsat 7 ETM+ image. As the two data sets are not homogeneous, the comparison for the detection of planimetric changes was performed on vector and raster data extracted from both data sets. For a rapid change detection process emphasis was given to increase the automation in the procedures. Texture measures and thresholding approaches were used to facilitate the extraction of certain map elements from the rasterized maps. For the image data, image and theme enhancements were performed by applying various image fusion (e.g., IHS, Brovey, PCA, PCI-IMGFUSE) and spectral enhancement (e.g., Tasselled cap, NDVI). Image thresholding and image classification were applied for the extraction of features from the imagery. Having defined and process the data sets for the epoch comparison, change detection was performed both visually and in an automated mode based on buffer zone generation and on the non-intersection of old and new features. The tests showed that besides the limitations posed by the resolution of the Landsat-7 imagery, both change detection and particular feature extraction operations were more or less feature/theme dependent. They also showed that visual change detection approaches can be improved when enhanced data sets are used, while the incorporation of image processing techniques supports the effort to automate the process. Throughout the whole process from data pre-processing to quantification of detected changes, different methodologies and techniques were presented for each step as well as their results including advantages and limitations. We hope that this will provide the reader with various options to be applied according to their specific needs and constraints in map updating operations. Research work needs to continue to provide improved methods and tools for rapid and flexible change detection and updating operations and to include linear elements.

REFERENCES

Armenakis C., F. Savopol, 1998. Mapping potential of the IRS-1C PAN satellite imagery. Inter. Archives of Photogrammetry & Remote Sensing, Vol 32, Part 4, pp. 23-26.

Armenakis, C. 2000. Differential approach for map revision from new multi-resolution satellite imagery and existing topographic data. Inter. Archives of Photogrammetry & Remote Sensing, Vol. 33, Part B4, pp. 99-104.

Chavez, P.S., S.C. Sides, J.A. Anderson, 1991. Comparison of three different methods to merge multiresolution and multispectral data: Landsat TM and SPOT panchromatic. Photogrammetric Engineering & Remote Sensing, Vol. 57, No. 3, pp. 295-303.

Cheng P., Th. Toutin, V. Tom. Orthorectification and data fusion of Landsat 7 data. ASPRS 2000, Washington, DC May 22-26 , 2000.

Harralick, R.M., 1979. Statistical and structural approaches to texture. Proceedings of IEEE, vol. 67, No. 5, pp. 786-803.

Heipke C., D.-M. Straub, 1999. Towards the automatic GIS update of vegetation areas from satellite imagery using digital landscape model and prior information. Inter. Archives of Photogrammetry & Remote Sensing, Vol. 32, Part 2W5, pp. 167-174.

Hayes D.J., S.A. Sader, 2001. Comparison of change-detection techniques for monitoring tropical forest clearing and vegetation regrowth in a time series. Photogrammetric Engineering & Remote Sensing, Vol. 67, No. 9, pp. 1067-1075.

Mather, P. M., 1987. Computer processing of remotely-sensed images. Published by Biddles Ltd., Guildford, Surrey, Great Britain, 352 p.

Ohlhof T., T. Emge, W. Reinhardt, K. Leukert, C. Heipke, K. Pakzad, 2000. Generation and update of VMAP data using satellite and airborne imagery. CD-ROM Intern. Archives of Photogrammetry and Remote Sensing, Vol. XXXIII, Part B4, Amsterdam, pp.762-768.

Singh, A., 1989. Digital change detection techniques using remotely-sensed data. International Journal of Remote Sensing, Vol. 10, No. 6, pp. 989-1003.

Sonka, M., V. Hlavac, R. Boyle, 1993. Image Processing, Analysis and Machine Vision. Chapman & Hall, London, Great Britain, 555 p.