Available online at www.sciencedirect.com
SCIENCE DIRECT®

Pattern Recognition Letters 27 (2006) 226–233

Pattern Recognition Letters

www.elsevier.com/locate/patrec

Detecting urbanization changes using SPOT5 ☆

V. Lacroix [a,*], M. Idrissa [a], A. Hincq [a], H. Bruynseels [b], O. Swartenbroekx [b]

[a] *Royal Military Academy, Signal and Image Centre, Avenue de la Renaissance 30, B-1000 Bruxelles, Belgium*
[b] *National Geographic Institute, Abbaye de la Cambre 13, B-1000 Bruxelles, Belgium*

Available online 28 September 2005

Abstract

An automatic system to estimate the urbanization changes on the Belgian territory, using SPOT5 images and the National Geographic Institute vectorial database is proposed. The images and the vectorial data are first co-registered. Then, the vectorial database is projected and dilated to produce a mask representing the old status of the database. On the other hand, a fusion of two classification processes on the images enables to extract the built-up area and the communication network, providing a mask representing the actual state of the urbanization in the zone. The comparison between the two masks gives a coarse information of the changes.

Keywords: Cartography; Change detection; SPOT5; Built-up area detection

1. Introduction

Demand for up-to-date geographic data is increasing, due to the fast changes in many regions, and as the result of the spreading of many GIS applications in everyday life. With the arrival of high resolution sensors, space images are becoming a good source of information to gather knowledge, and to track changes.

In a near future, the National Geographic Institute of Belgium (NGI) will manage its vectorial data ranging from a conceptual scale of 1:10 000 to 1:50 000 in one single database (DB). NGI is setting up a "planning tool" to schedule the data updating process according to the changes that occurred on the field and to compute the up-to-date status of the data as information to provide to end-users. The information about the changes will come from various sources, in particular, from remote sensed data. The sensor should be such that (i) the cost of a regular territorial coverage should be affordable; (ii) the regular territorial coverage should be technically possible; (iii) its resolution should enable the detection of changes in the built-up area and in the communication network. According to a visibility test (Lacroix et al., 2004), SPOT5 panchromatic 5 m resolution data fused with multi-spectral data seem sufficient for some photo-interpretor to detect most of sets of buildings, but not individual ones and most of the road network in open area.

In the following, we will first review some work in change detection, then expose the global strategy, and finally detail the proposed coarse change detection method.

2. State of the art

A summary of change detection methods can be found in (Li et al., 2002). Most articles deal with changes between images, and not with changes between a database and an image, often considered as a feature extraction problem. In (Vosselman and de Gunst, 1997), knowledge is used for updating road maps; the old road position is compared to the image using intensity profile. If change is observed, hypothesis of changes are made. While the incorporation of knowledge about possible lane widths and exit angles improves the interpretation results, many changes are in

☆ Colored figures are available at www.sic.rma.ac.be/Projects/ETATS_PRL/PRL.html. This study is funded by the STEREO program of the Belgian Science Policy.

* Corresponding author. Fax: +32 2 737 6472.
E-mail address: vinciane.lacroix@elec.rma.ac.be (V. Lacroix).

0167-8655/$ - see front matter
doi:10.1016/j.patrec.2005.08.003

fact false alarms because of disturbing objects like shadows, trees and cars. In (Busch, 1998), a method is proposed to perform the revision of built-up area in a GIS using satellite imagery and GIS data. The satellite images are SPOT and IRS-1C with a ground resolution of 10 and 5.8 m, respectively. The built-up area is detected on the basis of short edge densities. A threshold obtained thanks to training on GIS data is used to separate the built-up area. The changes are then observed comparing the classified zones with the GIS data. Klang (1998) proposed an automatic detection of changes in road DB using satellite imagery. The considered satellite data are Landsat, SPOT, IRS-1C, all re-sampled to 10 m resolution. The projected road vectorial DB is matched to detected roads. Statistics over the latter are used to find a threshold which serves at extracting seed points of potential new roads where a line tracking is started. Finally, the changes with the road data base are extracted. In an invited paper, Baltsavias (2002), provides the state of the art in object extraction and revision by image analysis using existing geospatial data and knowledge. The paper mainly focuses on multi-looking aerial images or satellite images of 1 m resolution. As far as the detection of man-made objects in satellite images is concerned, some researchers have also used NDVI and edges in the form of a complexity index (Sakamoto et al., 2004).

3. Overall strategy

Changes are located by comparing a mask generated by the DB projected on the image, to the output of a classifier extracting the built-up area and the road network, called the ''man-made'' or MM class. We assume that the built-up area and communication network generate structures and texture in the panchromatic image. Therefore, changes inside the ''old'' DB extent and changes in attribute such as the road width will probably not be noticeable. On the other hand, the system should detect as change, places where the DB indicates roads or buildings while they do not exist.

The strategy is summarized in Fig. 1. NGI's vectorial DB and SPOT5 images are the input of the system. NGI filters the DB to produce vector layers containing only the built-up area, the road network, and the hydrography. The road network and the built-up area are used to produce the ''Old Mask'', representing the old extent of the MM class. The images are registered with the vectorial DB using the data registration process. Then, on the one hand, the registered panchromatic image is analyzed by a ''Texture and Structure algorithm'' that separates textured from non-textured areas. On the other hand, the normalized difference vegetation index (NDVI) computed from the multi-spectral images, provides another two-classes separation: vegetation and non-vegetation areas. The fusion of both classifications from which the hydrological network is removed, is compared with the ''Old Mask'' to generate a ''Change Map''.

4. Data registration

If a digital elevation model (DEM) is available, ortho-rectified images can be produced ensuring that images are well-positioned under the vectorial layer. As NGI does not have a DEM on the whole Belgian territory, another solution is sought.

A set of ground control points (GCP), evenly distributed, are used to obtain a second order polynomial geo-referencing function g. If the RMS error of the vectorial DB projected with g^{-1} is larger than 5 m (a typical width of a secondary road), the image is cut in cells, and long bright lines are detected using the gradient line detector (GLD) (Lacroix and Acheroy, 1998); the latter exploits the fact that the gradient of the intensity is pointing towards/against each other at each side of a bright/dark line. Thus, in the 8-neighbourhood of each pixel, the maximum of the dot product of intensity gradient of symmetrical pixels is computed, if they both points towards the current pixel as seen in Fig. 2.

Then, a non-maximum suppression and line following is performed, as for edge extraction. Only long straight lines lying in the vicinity of the projected road network are considered as potential match. For each road, the best compatible line segments are considered, and a least square procedure (Borghys, 2001) is used to find the best local affine transform f_i fitting the detected lines of cell i under the projected vectors. The image is then re-sampled using bi-cubic interpolation.

The result of this process is shown in Fig. 3. If the RMS error in a cell containing a GCP exceeds 5 m, additional points are asked to the user, and another local function is computed. This option was not necessary over the two test areas (regions of Sint Niklaas and Brussels).

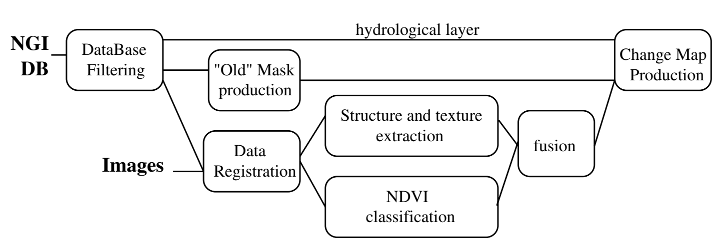

Fig. 1. The global strategy.