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Automatic change detection of buildings in urban environment from very high spatial resolution images using existing geodatabase and prior knowledge

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ABSTRACT

The updating of geodatabases (GDB) in urban environments is a difficult and expensive task. It may be facilitated by an automatic change detection method. Several methods have been developed for medium and low spatial resolution images. This study proposes a new method for change detection of buildings in urban environments from very high spatial resolution images (VHSR) and using existing digital cartographic data. The proposed methodology is composed of several stages. The existing knowledge on the buildings and the other urban objects are first modelled and saved in a knowledge base. Some change detection rules are defined at this stage. Then, the image is segmented. The parameters of segmentation are computed thanks to the integration between the image and the geodatabase. Thereafter, the segmented image is analyzed using the knowledge base to localize the segments where the change of building is likely to occur. The change detection rules are then applied on these segments to identify the segments that represent the changes of buildings. These changes represent the updates of buildings to be added to the geodatabase. The data used in this research concern the city of Sherbrooke (Quebec, Canada) and the city of Rabat (Morocco). For Sherbrooke, we used an Ikonos image acquired in October 2006 and a GDB at the scale of 1:20,000. For Rabat, a QuickBird image acquired in August 2006 has been used with a GDB at the scale of 1:10,000. The rate of good detection is 90%. The proposed method presents some limitations on the detection of the exact contours of the buildings. It could be improved by including a shape post-analysis of detected buildings. The proposed method could be integrated into a cartographic update process or as a method for the quality assessment of a geodatabase. It could be also be used to identify illegal building work or to monitor urban growth.

1. Introduction

The emergence of new satellite sensors (for example, Ikonos, QuickBird and Orbview) that are able to provide very high spatial resolution images (VHSR) is creating high expectations within cartography agencies (Holland et al., 2006). Thus, urban applications will be developed more and more, such as topographical mapping and map updating.

The updating process of a geodatabase (GDB) can be subdivided into three main steps: first, the land use changes must be detected. Second, several data sources must be used to add attributes to objects (for example, building type). Third and last, the changes and attributes must be integrated to the GDB. In summary (a) Detect Change, (b) Identify change, (c) Capture change. The change detection step is the most difficult (Walter, 2004). The approaches used most frequently to detect image changes are based on long and difficult interactive operations. For this reason, automation is important in order to facilitate detection and identification of changes.

Because of the high and accelerated rate of urban changes and the extension of urban areas, there is currently a growing interest in finding quick and efficient methods to map these changes and update the existing GDB (Baltsavias, 2004). With the use of VHSR images, new research possibilities for automatic change detection methods are open.

Automatic change identification is difficult. Human expertise is often called upon to identify the areas where changes occurred. It is even more difficult in an urban environment because of its complexity. It is characterized by a great diversity in limited areas' land use. Furthermore, the elements that constitute this environment (for example, roads, buildings) differ from rural and natural environments due to higher repeatability and smaller sizes. To take all these characteristics into account and thus improve the change detection results, it is imperative to develop an approach that uses

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all the information available on the objects studied such as color, texture and shape, as well as contextual parameters such as the relation with the neighbourhood.

On the other hand, the use of existing geodatabase allows the user to exploit additional information about objects to obtain better results. Currently, the approaches using geodatabase data are limited in most cases to the sole use of the objects' geometric information (Bailloeul, 2005; Baltsavias, 2004). Furthermore, the geodatabase data have traditionally been used mainly after the classification of the recent image and rarely during the classification process. This substantially limits their contribution.

In spite of all the solutions proposed by previous research, the automatic map updating based on VHSR satellite images remains an open matter of research (Bugnet et al., 2003; Gosselin et al., 2003; Baltsavias, 2004; Holland et al., 2006). This paper evaluates the potential for VSHR images to improve the update process of high scale urban maps. It is a contribution to automatic map updating in urban environments by using VHSR images and existing cartographic data. To limit the complexity of the problem we have focused on the building class that constitutes an important class in urban mapping. The proposed solution could then be adapted to other classes.

This article is organized as follows: Section 2 gives a short review of some change detection and map updating methods using the satellite images. Section 3 exposes the method proposed to detect building changes based on VHSR images and using existing cartographic data. Data used and preprocessing are presented in Section 4. Applications realized, results obtained and their analysis are given in Section 5. Section 6 is dedicated to discuss the methodology and the results.

2. Previous work

Several automatic methods have been proposed for the automatic detection of changes based on satellite images (Mas, 1999; Civco et al., 2002; Lu et al., 2003; Jensen, 2004). They vary between assisted methods and automatic methods, pixel-oriented methods and object-oriented methods, and between spectral characteristics based methods and artificial intelligence based methods. Two automatic change detection strategies can be identified: image–image comparison and image–map comparison.

2.1. Image–image comparison

Change detection approaches are traditionally based on image–image comparison, which consists in comparing, pixel by pixel, two images acquired at two different dates in order to produce an image which corresponds to the changes between these two dates. The most known change detection techniques can be divided into three main classes: techniques based on algebraic operations, techniques based on image transformation and techniques based on classification results. These techniques reviews can be found in Singh (1989), Coppin and Bauer (1996) and Lunetta and Elvidge (1999).

2.2. Image–map comparison

Image–map comparison consists of using an existing map to find the areas of change from a recent image. The problem of making a comparison between a map and an image is different from the one between two images because the map is an abstract and classified representation of reality. There are less numerous methods of comparison between a map and an image than those involving two images. Among the work performed, two types of methods can be differentiated: post-extraction change detection methods and map-guided change detection methods.

2.2.1. Post-extraction methods

Post-extraction methods consist of two steps: first, pertinent image primitives are extracted and secondly they are then compared to the map's objects. This approach is akin to the post-classification approach used between two images. In an image–map comparison, a spatial analysis is often used to detect the change. Thus, for a given theme (vegetation, road, building, etc.), the change is defined by non-intersection zones between the map and the image's objects. The change then consists of insertions and deletions. Insertions are obtained by the difference between the image's objects and the objects common to the map and image. Deletions are obtained by the difference between the map's objects and the objects common to the map and image. Examples of applications can be found in Walter (1999) and Armenakis et al. (2003).

The disadvantage of this type of method is the difficulty to extract all the objects from the image. In fact, errors caused by image classification influence the number of objects properly extracted. Thus, the missing objects as well as the objects falsely detected could be erroneously interpreted as changes when compared to the map. Furthermore, it cannot be assumed that the geometry and the shape of the objects extracted from the image will correspond to the ones of the objects indicated on the map.

2.2.2. Map-guided methods

Map-guided methods use the information extracted from maps to enhance the interpretation of the image. This kind of information is important, especially in complex environments such as the urban environment. The information derived from maps gives data on the location of the objects to be found on the image, allowing the user to reduce the search space and minimize false alarms. Fiset et al. (1998, 2003) and Bentabet et al. (2003) provide interesting examples of map-guided methods.

The use of these methods is based on the premise that the information on the map is very reliable. If the map is not very precise, it could bias the change detection process. Another difficulty linked to image map comparisons comes from the fact that the image and the map's objects are not represented in the same manner. Thus, it is important for image–map comparison methods to be able to take into consideration these difficulties.

2.3. Some applications for map updating

Research involving VHSR images has multiplied in recent years. In many European countries, research works in this field are performed in close collaboration with national cartography agencies. Walter (2004) proposes a change detection approach based on an object-oriented classification of remote sensing images. The approach classifies pixel groups that represent objects already existing in ATKIS, the German GDB, at a 1:25,000 scale. Training sites stem from this GDB. Every object is described by a vector of attributes and classified in the most likely class based on a maximum likelihood classification. Knudsen and Olsen (2003) combine supervised and unsupervised comparisons in order to locate new buildings and changes caused by building demolitions. This method has been evaluated based on data from TOP10DK, Denmark's map database. Cavayas (2004) presents work performed in order to validate the potential for IRS imagery to detect new roads and buildings and to update the content of the *base de données topographique de Québec BDTQ's* layers. Zhang and Couloigner (2004) propose an approach to update the Canadian National Topographic Data Base's roads. A multiresolution analysis and wavelet transformation combined to a road connections detection method and a data fusion technique were used to detect changes and update the database.

GIS data had not been sufficiently used in the change detection process. They were often used as a simple classification result to