APPLICATIONS OF TWO METHODS INTO URBAN DIGITAL MAP UPDATING FROM SATELLITE HIGH RESOLUTION IMAGES USING GIS DATA AS A PRIORI KNOWLEDGE.

Nasser Najibi[1] and Sepideh Rahbar[2], [1]Department of Surveying and Geomatics Engineering, Faculty of Engineering, University of Tehran, nsr.najibi@gmail.com [2]Department of Surveying and Geomatics Engineering, Faculty of Engineering, University of Tehran, s.rahbar.68@gmail.com

Abstract: In this paper, we propose two methods aiming at updating Geospatial Information System (GIS) urban maps using satellite high-resolution remote sensed images. Both methods are based on the input of a priori knowledge provided by GIS data, and a Digital Surface Model (DSM). This article introduces theoretical aspects of our methods; implementation is currently ongoing.

Introduction: Computerized map updating is a challenging task that has been tackled for more than twenty years. Indeed, manual map revision is a time and cost consuming process that makes automatic or semi automatic updating attractive. The need of up to date urban maps is worldwide; however it may be even more desirable in countries where the urban development is higher. Beijing, capital city of China is a site of special interest for urban change monitoring and map updating because of its rapid urban growth. The main reasons are the will to populate outskirts of Beijing city, the preparation of the Olympic Games in 2008 and the development of a sustainable environment. The objective of this work is to update outdated digital urban maps using recent information from high-resolution satellite imagery and prior information provided by maps. In other words, our task is to detect and analyze changes with localization (spatial detection), and identification (semantic interpretation). Two approaches are proposed for this purpose: the first makes use of a contour based segmentation approach; the second one focuses on a region-based segmentation. Both approaches are based on the use of a priori knowledge derived from outdated GIS data that constrains the segmentation process. The use of existing maps enables to gain specific information from the satellite imagery. It increases the confidence in object extraction processes compared to regular "bottom-up" approaches, which fail in dense urban environment sensed with a high resolution. Both methods will be tested on images and GIS data covering the north part of Beijing city

A. Input Data Sets

Multi-temporal acquisitions of Quickbird-2 multispectral images over the north part of Beijing city will be used. These images cover two main spots of interest: the future Olympic Village and the new "Silicon Valley". Satellite images have a 2.8 m resolution with a 14 m root mean square error accuracy; four spectral channels are available: regular red, green, blue (RGB) and NIR bands. Radiometric and geometric corrections were applied. Geometric corrections only deal with terrain rectification; super structures such as buildings are not ortho-rectified. The first satellite image acquisition was in March 2002.

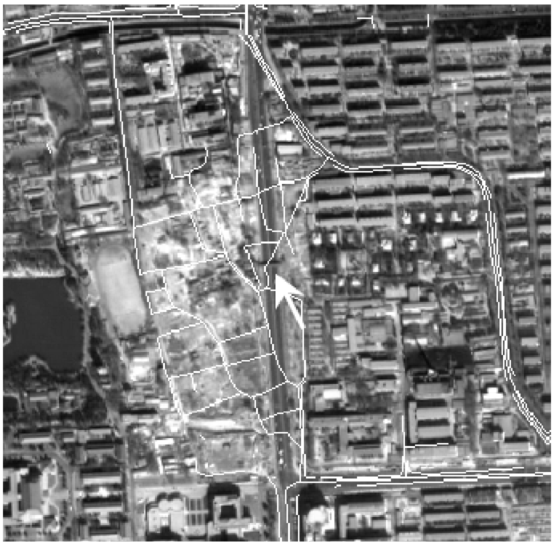

Fig. 1. Tshinghua University area, Beijing, China: GIS road layer displayed in white (1996) registered by global affine transformation on a Quickbird satellite image (2002). The white arrow points some changes.

Besides, a DSM will be computed using aerial RGB stereo-pair images. Aerial imagery is 1:10,000 scales, with 15 cm focal length and scanned with 21 microns resulting in 21 cm footprint images. The need of a DSM is twofold: first it is required to ortho rectify the satellite image from perspective distortion that affects its accuracy, second it is an additional source of information that may help the updating process in a complex and dense urban environment. The DSM will be computed by an edge preserving stereo correlation technique after having been projected into epipolar geometry [10]. Outdated urban digital maps are GIS data from 1996 and 2001 with a 1:10,000 scale. This vectoring data covers the Quickbird images area and contains the layers we will focus on: roads, residential areas, green spaces, rivers and stretches of water.

Buildings are modeled by polygons fitting the footprint; lakes and green spaces are delineated by the same kind of polygon. Open polygonal lines fit the sides of rivers and roads. GIS data does not provide any 3D information and has a 5 m geometric accuracy. Fig. 1 shows a GIS road layer from 1996 overlaid on a 2002 Quickbird image. Many changes are noticeable, especially concerning the road network. The white arrow points out a network of narrow streets replaced by a broad avenue.

B. First Method: Use of GIS Data and One Image

The main issue of this approach is to detect changes between outdated GIS data and a recent satellite image using *a priori* knowledge and deformable models. Assuming that over a one year period a few percentage of a urban environment has changed, we take advantage of *a priori* knowledge provided by existing GIS data to ease change detection: unchanged areas will be used for model refinement the models describe each "object", that is building, lake, road, etc that will enable pattern recognition on areas of the image subject to changes. Additional knowledge such as height or spectral information derived respectively from the DSM and satellite imagery will help to disambiguate the dense urban scene complexity. Buildings of the satellite image should be ortho rectified in order to improve the final updating accuracy of the GIS data. The method illustrated in fig. 2 can be described through the following steps:

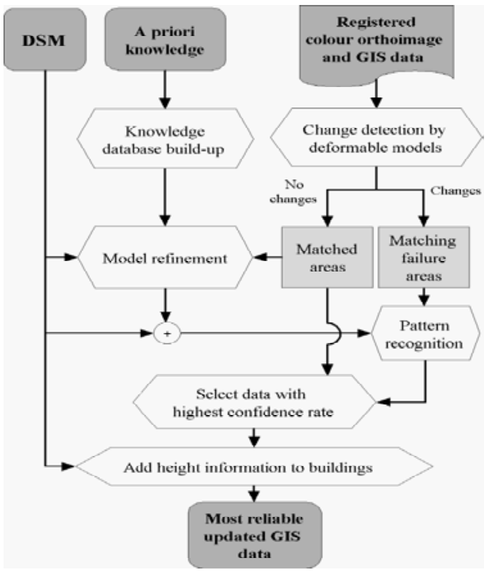

Fig. 2. Diagram synthesizing the first method for GIS data updating.

1) Global Registration: GIS data is overlaid on the satellite image by affine transformation based on an automatic method or manually detected control points (cf. Fig. 1). Unchanged areas between the existing digital map and the image should fit. First registration tries showed a good matching towards objects located on the ground (roads, lakes, rivers).

2) Knowledge database build-up: A priori knowledge provided by existing outdated GIS data (or layer maps) is used to define "object" models. The object classes are given by the layers of interest of the GIS data (roads, buildings...). Models are defined by the spatial and geometric information gained from the GIS data. General rules towards the objects composing the urban scene are also input to the knowledge database (e.g. buildings and roads do not overlap). At this step, the modeling is quite coarse. It will be later refined using some information specific to the image. This approach is similar to the work achieved in [13] towards road extraction.

3) Change detection: Deformable models initialized on the GIS objects are used to fit the corresponding objects of the image. If the matching succeeds for a given object, we can assume that no change occurred at that location. On the contrary,mismatching indicates change. Geometric constraints of the initialization enable to set up automatically the parameters of the models. Deformable models will be also constrained by previously defined rules and additional data (e.g. a deformable model initialized on a road side can not fit an object above the ground). Quantification of change detection reliability will be needed. At the opposite of the works achieved with *snakes* active contour ([1], [2], [11]), we do not expect deformable models to extract objects from the scene since this task is too complex and cannot handle new objects detection. Deformable models are constrained to change detection only.

4) Model refinement: Unchanged areas will be used to improve object modeling by gaining radiometric, texture and height information from the image and the DSM.

5) New objects recognition: Regions previously detected as "changed areas" are subjected to classification using the refined models. The output of this task is a semantic interpretation and localization of the changes: new objects are identified and spatially localized. Newly detected objects are vectorized to have a consistent representation with the GIS data. The confidence in new detected objects will also have to be evaluated.

6) Map updating: newly detected and unchanged GIS objects

With the highest confidence rate are merged to make the final updated GIS data. Buildings height derived from DSM is added.

C. Second Method: Use of GIS Data and Two Images

The input data of the second method should fulfill the following requirements: two satellite images represent a same scene acquired at a different time. The content of one satellite image is consistent with the GIS data that means no changes occurred between this image acquisition and the GIS data. Satellite imagery has to be ortho-rectified to enable accurate later registration with the GIS data. Since the content of one image is the same as the GIS data, we expect to discover changes between digital maps and the recent image through the changes between the two images. Prior spatial and thematic knowledge provided by the existing digital maps will provide training areas for subsequent supervised learning ([6], [12]). Besides, image-to-image change detection may divide the recent image into two regions: changed and unchanged areas. Then, changed areas of this image can be subject to classification with spectral, radiometric, or other statistical information gained from the former image. The output of that process is the extraction of new objects of the urban scene. At last, GIS data is updated according to classification results. The method can be summarized through the four following steps and fig. 3.

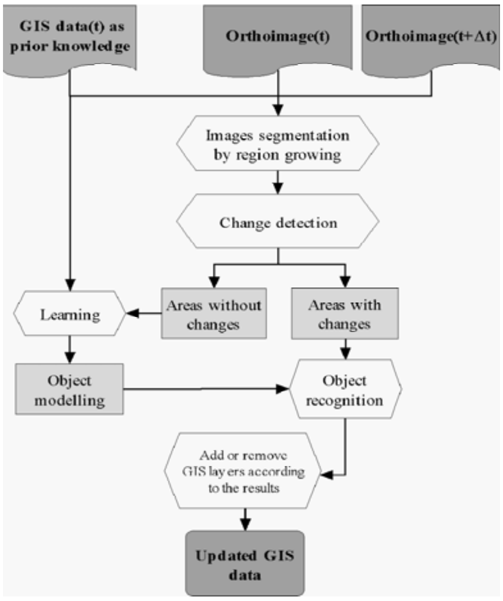

Fig. 3. Second method diagram for GIS data updating.

1) Registration: GIS data and the former ortho-rectified image are overlaid by an affine transformation.

2) Change detection: Segmentation by region growing is performed on both images for change detection. Each GIS object allows to determine a seed that initiates a region growing process at the same location of the sensed scene in the two images. A comparison of the two segmented regions in both images enables to state whether a change occurred or not. Moreover, the output of this process provides a segmented region in the former image for each GIS object. This may overcome erroneous registration and map digitization that prevent from perfect matching between the former image and the GIS data. Change detection based on region growing should yield: (i) areas in both images where no changes occurred. The corresponding areas in the former image enhance the spatial localization of registered GIS data. (ii) Areas in the recent image where changes occurred.

3) GIS-guided supervised learning and object recognition:

Regions without changes of the former image define areas for supervised learning. Therefore, layers of interest of the GIS data can be characterized by some radiometric, statistical, or geometric properties of the image. Objects can be recognized in areas of change belonging to the recent image according to the knowledge gained by this learning. New objects are then extracted by classification.

4) *GIS data updating:* objects extracted from changed areas are vectorized and inserted to the GIS database.

Conclusion

We have introduced two methods aiming at GIS map updating in an urban environment. The two approaches are based on image-GIS data fusion to make the urban map updating process more reliable. Compared to other methods using existing maps as prior information, our methods do not use GIS data as a rough approximation of objects that may be extracted in the image. We make use of high-resolution digital maps that can outline objects of the image. As a result, we take advantage of high quantity and quality of learning areas for later classification. A theoretical limitation of the first methodology is its intrinsic contour-based change detection. Therefore an object in the image that is semantically different from its GIS representation but which contours did not change, has no chance to be detected as different. This problem may only arise for object located on the ground since the DSM can disambiguate this critical situation. A limitation of both proposed schemes is the sensitivity towards GIS to image registration. Indeed, a mistaken registration may cause wrong change detection and inaccurate supervised classification for both approaches. Further works will be dedicated to reduce the dependence towards the registration quality. Confidence quantification of change detection and object extraction will be carried out in the future implementation of the methods.

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