AUTOMATIC CHANGE DETECTION OF GEOSPATIAL DATABASES BASED ON A DECISION-LEVEL FUSION TECHNIQUE

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ABSTRACT:

Monitoring of changes in topographic urban geospatial databases (UGDs) is one of the main requirements of urban planners, urban decision-makers and managers. In this paper, an attempt has been made to design an automatic change detection (ACD) solution. The approach presented here takes advantage of fusion of descriptive and logical information represented on two levels. That is, information fusion to exploit the multi-level characteristics of the objects and logic fusion for enhancing the learning and with this the recognition abilities of the system. The proposed ACD process utilizes two types of data sets. Firstly, aerial and satellite images are used as data sources for the generation of a Digital Surface Model as well as for extracting textural and spectral information. Aerial images, because of their geometric stability, provide metric information, and satellite imageries, due to their wealth of spectral information, generate spectral data. The second type of data is the topographic urban geospatial databases. These data sets provide reference information, whereas the aerial and the satellite images serve to generate the more recent information and changes. The change detection process includes object identification, object extraction, object recognition and change detection phases. The proposed automatic change detection methodology was tested on a 1:1000 scale digital map of the city of Rasht in Iran by using of 1:4000 aerial photos and a pan-sharpened IKONOS scene. Visual inspection of the obtained results demonstrates the high capability of the proposed method.

1. INTRODUCTION

High and accelerating rate of urban changes, in particular in the developing countries, calls for an efficient and fast technique for mapping the changes with the required accuracy for updating the existing topographic urban geospatial databases (Dowman, 1998; Armenakis et. al., 2002; Kim and Muller, 2002).

However, in practice most of the processes for analysing the changes are the manual methods like on-screen change detection that are time consuming and expert dependent. The availability of the new generation commercial one-meter resolution satellite imageries, due to their wealth of information content, have opened a new era in the problem of automatic change detection and consequently the UGDs updating. Therefore, automatic change detection has been an area of major interest in remote sensing and GIS for the last few years (Peled, 1993; Darvishzadeh, 2000; Dowman, 1998; Armenakis et. al., 2002; Kim and Muller, 2002; Schiewe 2002; Shi and Shibazaki, 2000).

Regarding the human potentials in object perception and recognition, it seems that a comprehensive automatic UGD change detection system should be able to integrate the capabilities of: a) All available descriptive information components of an object (such as: structure information, textural information and spectral responses) must be simultaneously taken into account. b) A fuzzy formulation for

the object definition, regarding its complexities, should be devised. c) Learning capabilities to modify the defects accompanied by the objects definition needs to be considered. This will enhance the recognition potentials when encountering new and undefined objects.

Nevertheless, most of the existing methods for doing change detection process are basically optimized to use information of one sensor imagery and in addition, by employ parametric methods, object's fuzziness behaviour and the possibility for introducing training potentials are basically neglected. In this paper, for the first time, an attempt has been made to design a system that integrates all above features in a total and comprehensive automatic change detection (ACD) solution. The approach presented here takes advantage of the concept of fusion in two levels of descriptive information and logical planes. That is, information fusion to exploit the multi-level characteristics of the objects and logic fusion for enhancing the learning and hence recognition abilities of the system.

2. PROPOSED METHODOLOGY

As shown in the Figure 1, the proposed ACD process utilizes two categories of the data sets. In the first category, raster aerial and satellite images are used as data sources for the generating a DSM (using stereo digitized aerial photographs), textural information (using both image and satellite images) and spectral information (using satellite image). That is, aerial images, because of their geometric stability, provide

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metric information, and satellite imageries, due to their wealth of spectral information, generate spectral data. The second category of the data sets is the topographic UGD (i.e. 3D digital map vector data).

These data sets provide reference information, whereas the aerial and the satellite images serve to generate the most recent information and changes. To facilitate the ACD operations, sets of pre-processing modules are initially applied to the input data. These are basically fundamental radiometric and geometric corrections of aerial and satellite imageries such as the grey scale filtering, the determination of the sensor attitude and altitude parameters and registration. More particularly, as the proposed workflow (Figure 1) indicates, the change detection process is conducted under: object identification, object extraction, object recognition and change detection phases.
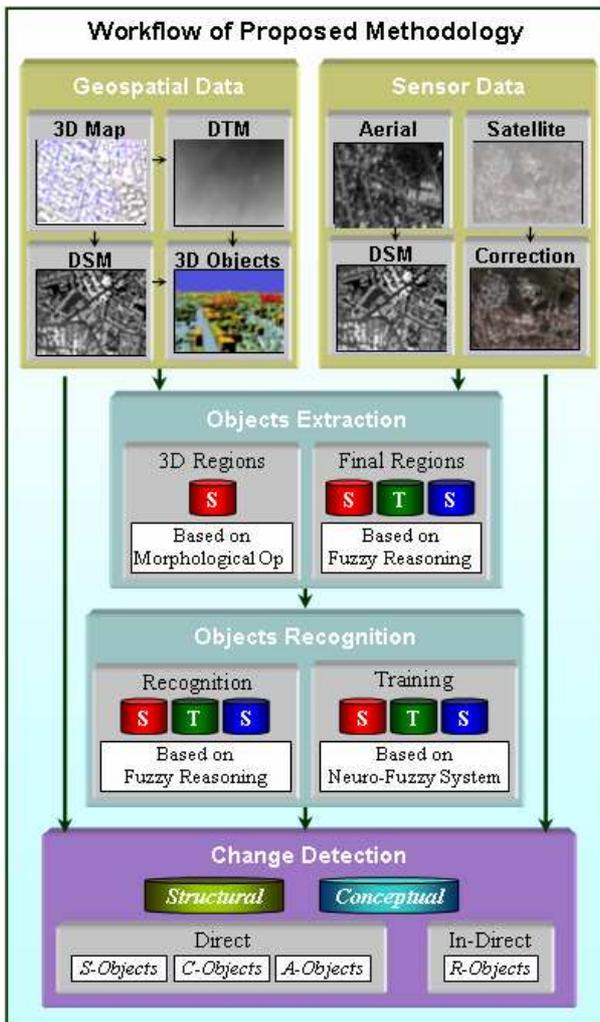
Figure 1. Workflow of presented method for automatic object recognition and reconstruction

3. EXPERIMENTS AND RESULTS

The proposed automatic change detection methodology was tested on a 1:1000 scale digital map and a pan-sharpen IKONOS scene of the city of Rasht, Iran (Figure 2). The maps have been produced in 1994 from 1:4000 aerial photographs by National Cartographic Centre (NCC) of Iran.

The satellite imagery was acquired on May 28th 2001. During these seven years time lapse between the generated digital map data and the IKONOS image acquisition, considerable changes have occurred in the city (See Figure 2).
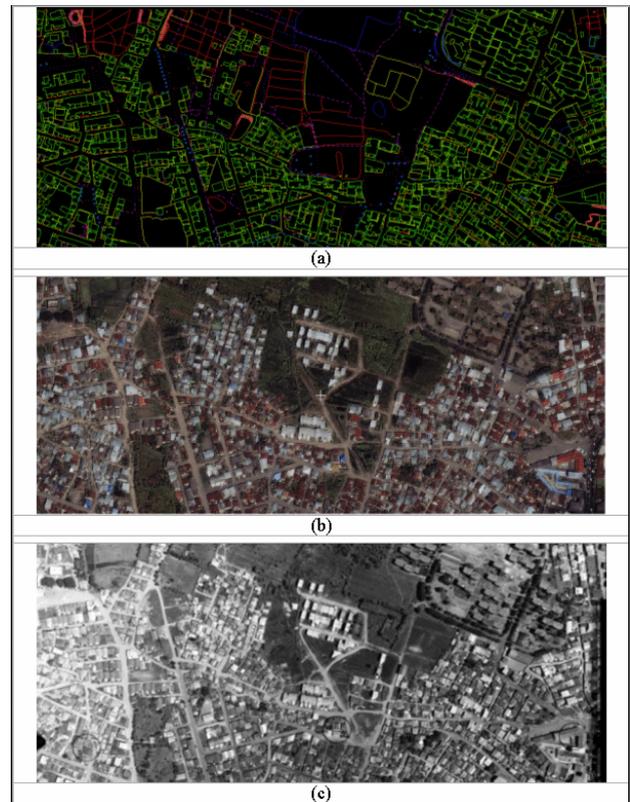
Figure 2. 1:1000 planimetric map of the city of Rasht (a), corresponding IKONOS Pan-sharpen (b), corresponding aerial photo (c).

For two object classes of building and tree, the preliminary membership functions for the structural, textural and spectral information (STS) components are defined based on the knowledge of an experienced photogrammetric operator.

Where membership functions can initially not be defined with sufficient confidence, they are tuned and modified by the learning potentials of the neuro-fuzzy technique. For the initial training operations of the system, 200 samples as learning data set and 50 samples as the checking data set were selected. The more samples are used the more comprehensive the membership functions would be defined and hence more reliability for the recognition process. To test the adaptation potentials of the recognition process for the modification of the membership functions, 200 samples were selected so that a great variety of viewing appearances for the building and tree object classes are covered. Based on these preliminary training operations the adjusted membership functions were determined. To assess the capabilities, reliability and efficiency of the proposed ACD method a portion of an urban portion of this area is selected. The selected area is well suited for first experiments with the proposed ACD method and shows a significant complexity as regards the proximity of the objects. The results of our ACD strategy is presented in Figure 3. The visual inspection of the obtained results demonstrates the high capability of our strategy.
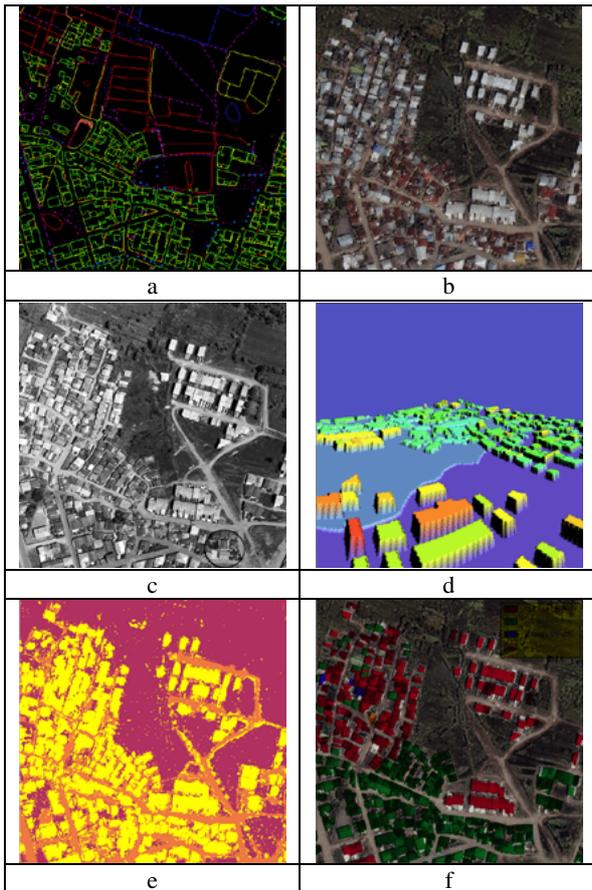
Figure 3. 1:1000 planimetric map of the city of Rasht (a), corresponding IKONOS Pan-sharpen Patch (b), Corresponding Aerial Patch (c), Extracted 3D objects in test area (d), Classified Objects (e) and Final result of proposed automatic change detection methodology in the test area (f).

4. CONCLUSION

The obtained results by applying our proposed strategy on different kinds of objects from natural to man-made GIS objects established the high capability of our proposed ACD strategy. The main feature of this strategy is not so much its individual modules that perform different tasks, but the methodology itself that governs the entire system. Our methodology is based on these premises: (1) Simultaneous fusion of all available information for the object extraction and recognition. In our case these were limited to the three STS components. However, it can be extended to include other possible descriptive attributes if they are available. (2) Because of the fuzzy behavior of the objects, a rigorous and crisp modeling approach for extraction and recognition problems should be avoided. (3) Taking into account the numerous varieties of the objects types and appearances, training potentials are a real necessity for an ACD method. (4) Within the general scope of the proposed methodology, individual modules such as matching operation, surface modeling, region growing, structural and textural analysis,

etc. can be improved parallel with the related algorithmic developments.

We believe our proposed ACD strategy has demonstrated a promising and comprehensive solution to a complicated problem, however, we are still far from reaching to a perfect solution for a fully automatic ACD system. Bearing in mind the general concepts presented above we may outline the future research works based on the following proposals:

- Implementation of a hybrid neuro-fuzzy approach by which recognition parameters as well as fuzzy rules are trained and modified.
- Algorithmic improvements should be investigated for individual modules govern the extraction, recognition and reconstruction phases.

5. REFERENCES

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6. ACKNOWLEDGEMENTS