A FRAMEWORK FOR AUTOMATED CHANGE DETECTION SYSTEM

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ABSTRACT To enhance the ability of remote sensing system to provide accurate, timely, and complete geo-spatial information at regional or global scale, an automated change detection system has been and will continue to be one of the important and challenging problems in remote sensing. In this paper, the authors propose a framework for automated change detection system at landscape level using various geo-spatial data sources including multi-sensor remotely sensed imagery and ancillary data layers. In this framework, database is the central part and some associated techniques are discussed. These techniques includes five subsystems: automated feature-based image registration, automated change finding, automated change feature extraction and identification, intelligent change recognition, change accuracy assessment and database updating and visualization.

1 Current change detection techniques

Automatic change detection in images of a given scene acquired at different times is one of the most interesting topics of image processing. It finds important applications within different contexts, ranging from visual surveillance and video coding to tracking moving objects, from map updating to environment monitoring (Rosin, 1999). The basic assumption behind change detection is that any changes on the ground must result in changes in radiance values, so the changes must be detected from noise by other factors, such as differences in atmosphere conditions, illumination condition, and relief condition, differences in soil moisture and registration noise.

Usually, change detection involves the analysis of two registered multi-spectral remote sensing images acquired in the same geographical area at two different times. In the remote sensing literature, two main approaches to the change detection have been proposed: the supervised and the unsupervised approaches. The former is based on supervised classification methods, which requires the availability of a multi-temporal ground truth in order to derive a suitable training set for the learning process of the classifiers. The latter performs change detection by making a direct comparison of the two images considered without relying on any additional information.

Post Classification Comparison and Direct Multi-date Classification are the commonly used techniques in the supervised approach. Post Classification Comparison is the most intuitive technique in the practice of change detection techniques, which simply classifies the images of two times separately and compares the classified maps on a pixel-by-pixel basis to identify the changes. In contrast, the Direct Multi-date Classification deals with the multi-spectral images of the two times simultaneously. Each change combination between two times is represented as an output class and the whole change
The detection process is treated as a classification. The supervised approach exhibits some advantages over the unsupervised one (e.g., capability of explicitly recognizing the kind of land cover transitions that have occurred, robustness to the different atmospheric and light conditions at the two acquisition times, ability to process multi-temporal and/or multi-sensor images). The disadvantages include greater computational and labeling requirements, severe difficulty in obtaining individual classification accuracy and difficulties inherent in performing adequate accuracy assessment on historical data sets. Another drawback is the generation of an appropriate multi-temporal ground truth is usually a difficult and expensive task (Bruzzone, et al., 2000). Consequently, the use of effective unsupervised change detection methods is fundamental in many applications in which a ground truth is not available.

The most widely used types of unsupervised change detection techniques is the so-called “difference image”. These techniques involve image difference, image ratio, change vector analysts (CVA), principal component analysis (PCA) and other methods such as neural network, morphological mathematics. They process the two multi-spectral images acquired at two different dates in order to generate the further image. The computed difference image is such that the values of the pixels associated with land cover changes present values significantly different from those of the pixels associated with unchanged areas. Changes are then identified by analyzing the difference image. For example, the image difference technique generates the difference image by subtracting pixel by pixel, a single spectral band of the two multi-spectral images under analysis. The choice of the spectral band depends on the specific type of change to be detected. An analogous concept is applied by the widely used change vector analysis (CVA) technique. In this case, each pairs of corresponding pixels is represented by two vectors in feature space called change vectors. The change vector takes the difference between the feature vectors at the two times. The magnitude of the change vector represents the degree of change, while the direction of the change vector indicates the types of change with the help of supervision on the change types. In spite of their relative simplicity and widespread use, the above mentioned change detection techniques exhibit a major drawback: lack of automatic and non-heuristic techniques for the analysts of the difference image. In fact, in classical techniques, such an analysis is performed by thresholding the difference image according to the empirical strategies or manual trial-and-error procedures, which significantly affect the reliability and accuracy of the final change detection map. Although many analysis proposed a lot of automatic threshold selection methods (Rosin, 1999; Quere, 1997; Bruzzone, 1999), they are only suitable for some specific situations.

2 Problems & requirements

There are ten major problems associated with the current change detection techniques.

1) Lack of theoretical basis for change detection is the key problem. Many change detection techniques can detect some change information in some specific situations, but when the situations changed, the results changed. In fact, because of the complexity of image problems, it is difficult to illustrate one kind of universal truths.

2) This is the concess for the first problem. Even if we have no universal theory for change detection, it is practical to have some criterion for selecting different change detection techniques according to different situations. But this point is still not achieved.

3) Most change detection techniques are based on pixel level. But generally speaking, a mere thresholding of the difference signal obtained from two corresponding pixels was insufficient to distinguish changes of interest. So some feature-based algorithms should be developed for improving the reliability and accuracy of detection.

4) We have too little information about spectral characteristics of ground objects. This affects our understanding of images. Of course this task is very time-consuming and expensive.

5) It is obvious that very limited information and/or knowledge (about sensors, images, spatial
relations and so on) is utilized in current change detection techniques.

6) Finding change (i.e. the amount of change detected) is one of the most important objectives in change detection applications, but most of the current change detection techniques need a user-specified threshold which is often set empirically and subjectively since there is no theoretical guidance to this problem.

7) In most change detection techniques, the dependency information between the two images is ignored.

8) Only very limited or no information at all about the direction and characteristics of actual changes occurred on the ground can be induced using most current change detection techniques (Dai, 1998).

9) One practical problem with difference image is that the images are not in perfect spatial registration before analyzing so the difference image will contain artifacts caused by incomplete cancellation of the unchanged background objects. This registration noise causes problems for most change detection algorithms (Dai, 1998).

10) Most techniques are not fully automated and some are even non-quantitative.

In summary, many interactive change detection techniques are in practice today. However, the majority of the techniques themselves can only provide the binary change mask and classification procedure must be applied to the individual multi-temporal images in order to obtain the categorical information of multi-date land covers. Besides, analysts have to manually process many critical tasks related to image processing, feature extraction and feature delineation and so on. There are many problems associated with these manual or semiautomatic process such as time-consuming, inconsistency, and being difficult to apply them to large-scale and global information systems. Therefore, a reliable and automated change detection system is required.

3 A framework for automatic change detection

This research is designed for the development of a framework for automatic change detection. On the basis of the research an automated spatial change information extraction system from various geo-spatial data sets will be created. This study has four interrelated subsystems as shown in Fig. 1. In the first subsystem, we proposed to develop an automated image registration subsystem that registers images accurately and quickly with little or no operator supervision. After automatically registered images, an automated change finding subsystem, which takes multi-sensor and/or multi-temporal, space-borne and/or air-borne, remotely sensed imagery as its inputs, and finding changed area would be developed. In this subsystem, the output change information is divided into two groups: certain information (the changes with minimal uncertainties that can be easily extracted on the basis of spectral and perhaps some other image characteristics) and uncertain information (the changes involving high-level uncertainties). The uncertain information is...
then presented to the second subsystem: automatic change feature extraction and identification subsystem in which changed image features (edge and area) are extracted. The changed information enters the fourth subsystem: intelligent change recognition subsystem that is built upon knowledge-based technique utilizing knowledge stored in the database. In this subsystem, the changed magnitude, changed type will be recognized by some recognition algorithms. The procedures to reduce uncertainties including verification and accuracy assessment of both certain and uncertain changes are explicitly built into the proposed methodology. This is the fifth subsystem. Finally, the identified and recognized changed features are transmitted to information update system for data update and visualization for decision and policy-making purpose.

3.1 Automated image registration subsystem

In automated change finding subsystem, the impact of misregistration on remotely-sensed change detection is quantitatively investigated and potential techniques to remove or reduce this impact is developed. Because of anticipated large data volume and high data rates of these current and future high-resolution sensors, the traditional approach of visual identification of tie-points to register multi-temporal and multi-sensor data is not an acceptable solution. The elements of this procedure include image segmentation, control point selection and correspondence, transformation parameter estimation and so on. An automated feature-based image registration procedure is one of the choices. Knowledge about matching control points and recognition can be obtained from database.

3.2 Automated change feature finding subsystem

After accurate registration, the authors use the image difference technique (one kind of widely used change detection techniques) to get the difference image. The selection of threshold is automatic and the algorithm is suggested by Bruzzone (2000). Because of the difficulty and uncertainties of threshold selection we can not obtain the very precise changed area, however, it is possible to identify those areas with larger probability (this is certain change information). And those area with smaller probability would belong to uncertain change information naturally. Obviously, this procedure is based on pixel level.

3.3 Automated change feature extraction and identification subsystem

For certain and especially uncertain changed information, the best way to discriminate them is to analyze further with additional information. The main features in images are edges and areas which are the most important factors for object recognition. Although radiance values in images change at two different dates because of the differences in atmosphere conditions, illumination condition, relief condition, noise and so on, the basic shape and outline of features in images always keep invariant. So some image processing algorithms such as edge enhancement, edge detection, area segmentation and edge extracting are applied to the system. The goal of extraction of a lot of edge and area image features lies in three aspects. One is to compare them between the two images to identify changed area, another is to prepare image features to be recognized, and the third is to update the database using changed image features. For those uncertain changed areas they are subdivided into smaller changed and unchanged areas. And for those certain changed ones this comparison is a confirmation procedure. When finding some conflict results this area will be subdivided. It can be seen that this subsystem is based on feature level.

The algorithm is one of the important techniques about comparison of features. Take one image as a reference image, features on another image are selected for searching the matching results in reference image with maximum similarity one by one. How to define similarity? For different features (i.e. edge in the reference image and area in another image), it is an easy task. But indeed it is a confusing problem for the same features. Obviously accurate comparison is not a good choice because the features themselves contain uncertainties. So using tolerance is an advisable method. Here one factor called ‘buffer distance’ is introduced. The so-called buffer distance is a tolerance distance in which two same features are identified equivalently. Commonly
the buffer distance is 2–4 pixels in images.

3.4 Intelligent change feature recognition subsystem

After finding changed area and identifying change feature, another important step is to recognize changed feature and classify them to different attribute classes. In this procedure, many classification algorithms can be combined to get the right results. However, because these algorithms always bring unreliable information some knowledge-based feature and attribute extraction and recognition systems have to be developed. The used knowledge can be obtained from database. A knowledge representation scheme is employed, which consists of three components: context, rule base and interpreter. The inference strategies employ the mixed model combined with data-driven and model-driven models. In the decision procedure, Dempster-Shafer theory is applied to process all kinds of information including some conflict information. Learning is one of the most important functions of this subsystem. Learning is to adapt different situations. Learning results will be updated and put into the database.

3.5 Database

Database is the central part which includes not only data related to environment, resources, land cover, terrain, urban and other aspects, but also knowledge which is discovered or undiscovered, stationary or dynamic, common sense or domain and so on. On one hand, database provide information and/or knowledge for the above three subsystems, for example, knowledge for automated feature-based image registration, feature extraction algorithm and feature connection rule for automated change feature extraction and identification subsystem, inference strategies and knowledge base for intelligent change feature recognition subsystem. On the other hand, the data and knowledge obtained from these subsystems will be transmitted into the database. From the viewpoint of database itself, it is not stationary and invariant but dynamic. That is to say, evolution from data to knowledge by KDD system always occurs in the inner part of the database. This keeps the freshness of database. Fig. 2 shows database with dynamic behavior in which knowledge is discovered from data by KDD system.

4 Conclusion

The need for an efficient, accurate, intelligent automated change information extraction and recognition system from remotely sensed data will continue to rise. This research area will continue to increase in interest as the data volume becomes larger, data rates become higher, and the image processing ability of machines becomes stronger. Of importance is to integrate multi-source data, utilize all kinds of knowledge for better decision and use parallel processing algorithm to improve the efficiency in the future remote sensing system.

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