AUTOMATIC CHANGE DETECTION OF GEO-SPATIAL DATA FROM IMAGERY

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ABSTRACT:

Automatic change detection and data updating is a very important issue for keeping the temporal accuracy and currency of spatial data sets. The problems and difficulty of current change detection techniques are presented in this paper. According to whether registration is done before change detection algorithms, authors classify change detection into two categories: change detection after image registration and change detection simultaneous with image registration. For the former, four topics including change detection between new image & old image, change detection between new image & old map, change detection between new image/old image & old map, change detection between multi-source images and old map/image are introduced and described. For the latter, three categories that is change detection between old DEM, DOM and new non-rectification image, change detection between old DLG, DRG and new non-rectification image, 3D change detection between old DEMs, DOMs and new multi-overlapped photos are discussed in the paper. At last the conclusions are given.

1. INTRODUCTION

Geographic information System (GIS) technology is a multibillion-dollar industry worldwide. Experts in many areas (from lawyers to engineers) are using GIS today at an increasing rate to analyze and answer questions related to geographic areas. GIS is without doubt the most efficient way to analyze and query geographic data. From the viewpoint of quality, there are several factors that affect geographic data. One of the most important factors is the currency. Demand for up-to-date geographic data is increasing due to the fast change of real world especially in urban areas. GIS analysis and query using outdated geographic data will provide results that are valid for the situation the data represented. For example, in the United States, the most precise nationwide coverage is provided by the 7.5 quadrangle series and its digital equivalent (the DLG files available only for a small percentage of the whole country). The average age of the quadrangles is 25 years. The use of GIS based on this data provides answers that were valid 25 years ago.

The currency of geo-spatial data is the soul of GIS development. However, the current updating status is not optimistic. According to the statistics of united nation, the updating period of 1:50,000 and 1:250,000 maps is 50 years and 20 years! It is obvious that this updating speed can't satisfy with the development requirements of modern information society. In china, the currency of 1:50,000 and 1:250,000 maps terminates at 1997. The future updating work is very huge and time-consuming. However, because of lack of efficient updating techniques, people are suffering from how to keep their database "fresh" with low cost and high frequency. In fact, to keep a database "fresh" or "current" is one of the biggest "bottle-neck" that obstacle the application and promotion of GIS.

There are two approaches for updating geo-spatial databases. The first one is to gradually establish a new database that replaces the old one. This approach is slowly. it is suitable for new database building for new area. The second approach is only to detect, identify and update only the changes. It is quick and suitable for those existence databases. Obviously automatic change detection is the first and the most important step of automatic updating geo-spatial databases. Without automatic change detection, it is no any meaning for discussing automatic geo-spatial data updating.

Automatic change detection in images acquired at different times is one of the most interesting topics of image processing. 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, differences in illumination condition, differences in relief condition, differences in soil moisture and registration noise. Although the research work for change detection is not a new topic, but most of them care about the algorithm itself. From the top level of change detection algorithms, few researchers can give very systematic study. Even if some literatures give discussion, but it is not all-around. This paper gives systematic and conceptual description for the summary of change detection techniques.

The remainder of this paper is organized as follows. Section 2 described the existence problems and difficulties of automatic change detection. In section 3 a very detailed discussion for classification of change detection techniques is presented. Section 4 concludes this paper with further recommendations for our future research works.

2. PROBLEMS AND DIFFICULTIES

There are twelve major problems associated with the current change detection techniques (Haigang Sui & Deren Li,2001):

- 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.

- Even if we have no a universal theory for change detection, it is feasible that we have some criterion for selecting different change detection techniques according to different situations. But this point is still not achieved.

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

- Automatic features extracting and recognition from imagery is always a very difficult problem and the progress is slowly. It is the "bottle-neck" problem of change detection based on features.

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

- Often we have no good methods for processing the bad effects on image such as uncertain atmosphere conditions, sensor noises, radiometric differences and so on. These factors cause the low accuracy of change detection.

- Considering how humans detect changes from images, 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.

- 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 theoretical guidance to this problem.

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

- 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 (Xiaolong Dai,1998).

- 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 (Xiaolong Dai,1998).

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

Although through 40 years of research and efforts for change detection, and some semi-automatic software for change detection has come forth, automatic change detection is still a dream. The reason lies in that there are many difficulties to be faced with. These difficulties are as the following:

a) The difficulty of automatic extracting and recognizing objects from imagery. Although a lot of automatic and semi-automatic objects extraction methods have been proposed and developed. These methods are only effective in the special cases. For buildings extraction, when there are no explicit or complete shadows in images or there exist very complex and irregular roofs, the density of buildings is high (in this case, high quality DSM and DEM is very difficult to be obtained) and occlusions, most of these systems may meet difficulties to work automatically and efficiently. For road networks extraction, trees, cars, occlusions as well as other objects on roads or around roads destroy the homogeneity that let the automatic extraction very difficult.

b) The difficulty of automatic acquiring knowledge. After more than twenty years of efforts for automatic extracting objects from imagery, people have realized that overcoming this big problem must utilize knowledge. However, how to acquire knowledge, represent and utilize them is a puzzled problem. The KDD and DM techniques are the possible methods for acquiring knowledge.

c) The difficulty of automatic rectification and registration. Automatic rectification and registration are the first step for automatic change detection and other image procedures. Many researchers make much effort for them and they obtain some exiting achievements. But it is a long way to achieve practical levels. The big obstacle is still the automatic feature extraction and recognition.

d) The difficulty of integration multi data sources. Traditionally, the main data source updating GIS database is the remote sensing images. The images from several sensors always need to be fused for updating geo-spatial data. And images fusion is also a puzzled problem. In fact, except for image sources, other types of data sources (such as administrative information, urban plan information and so on) are also necessary for updating. That is, the integration or fusion data sets is needed. However, since each data set has its own special properties (e.g. resolution, accuracy etc.) and reference system, to integrate them is not a easy work.

3. CLASSIFICATION OF CHANGE DETECTION TECHNIQUES

Generally, some pre-processing such as image rectification, image registration and other procedure is necessary before change detection. This is the common approach. Another recommendatory approach is to detect changes simultaneous with image registration. So according to whether registration is done before change detection algorithms, we classify change detection techniques into two kinds: one is change detection after image registration, another is change detection simultaneous with image registration. The former focus on change detection algorithms themselves, the latter not only emphasizes the change detection algorithms but also the mechanism of image registration. Obviously, The former is relatively simple and can inspire people's ability to adjust all kinds of unexpected situations, but it is time-consuming and complex. And it is not suitable for some special cases such as real time application like military reconnaissance, or in the situation that people can't (or difficult to) obtain the control points for image registration. Moreover, the errors brought by image registration can produce negative effects on the procedure of change detection. Although the latter can avoid these effects, it is more difficult and very few researchers gave attention to it.

3.1 Change Detection after Image Registration

In the most of change detection research or projects, we always pay more attention to the techniques and algorithms themselves. In fact, from the viewpoint of data sources, different data source can produce huge difference for strategy and algorithms of change detection. According to different application and data sources, we can further classify this approach into four categories:

- Change detection between new image and old image
- Change detection between new image and old map
- Change detection between new/old images and old map
- Change detection between multi-source images and old map/image

3.1.1 Change Detection between New Image and Old Image

Using multi-temporal new and old images for change detection is the most popular method in change detection application. The method can be called PLCD (Pixel-Level Change Detection). Generally, rectified ortho images produced from both images based on the external orientation parameters of each single image are used as the data sources instead of origin images. The changes are detected by direct/indirect compassion of two images from different dates. This comparison assumes that the differences between the radiometric signatures are due to the changes of object characters. Indeed, these differences could be a result of other factors, such as different atmospheric conditions, changes of sun light angle and intensity, general noises, rectification errors etc. To avoid the effects of these factors, a radiometric calibration must be implemented. This can be achieved by many methods, e.g. a histogram-matching procedure. The scheme of this approach is shown in Fig 1.

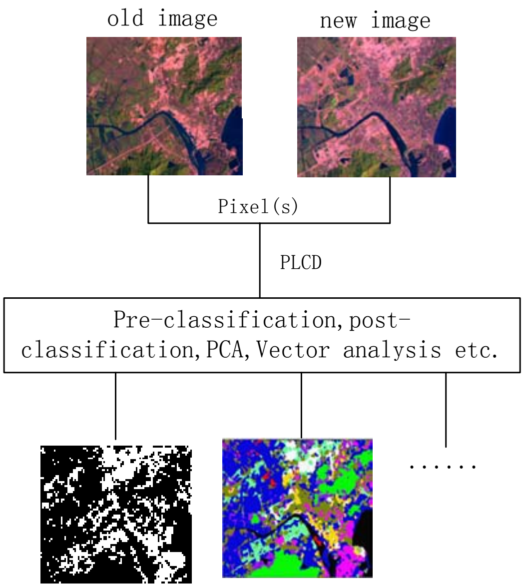

Figure 1. The scheme of change detection between new image and old image

Many different types of change detection methods were developed and reported in theprofessional literatures (Macleod R.D,1998;Sohl T.L,1999;Sunar F.,1998;et.al). Many authors have suggested classify change detection into two kinds: one is pre-classification and another is post-classification. The former performs change detection by making a direct comparison of the two images considered without relying on any additional information. The latter is based on supervised classification methods, which require the availability of a multi-temporal ground truth in order to derive a suitable training set for the learning process of the classifiers. Pre-classification is mainly to create the “difference images. It involves image difference, image ratio, change vector analysis(CVA),principle component analysis(PCA) and other methods such as neutral network ,morphological mathematics. They process the two multi-spectral images acquired at two different dates in order to generate the further image. Post-classification is the most intuitive techniques in practice change detection, which simply classifies the images of two times separately and compares the classified maps on a pixel-by-pixel basis to identify the changes.

The lack of pre-classification lies in automatic and non-heuristic techniques for the analysis 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 analysts proposed a lot of automatic threshold selection methods (Rosin,1999; Quere ,1997, Bruzzone 1999),they are only suitable for some specific situations not for common use. The disadvantages of post-classification 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.

3.1.2 Change Detection between New Image and Old Map

Using images to revise GIS database is one of the most applied widely updating methods. Here, the authors call this method PLCD (Feature-Level Change Detection). In general, automatic updating includes the following three steps:

a) Automatic change detection
b) Integration changed information into GIS database
c) Post-processing and consistency checking

In this procedure, automatic change detection is the first and the most important step(Peled,1996,2000). Because of the differences of reflecting reality levels between image and map, it is impossible to compare two kinds of data source directly. It is a natural method to extract features from the new image and use them to detect the changed parts of old map. Obviously automatic features extracting is the key problem in this approach. In the past twenty years, researchers from photogrammetry, remote sensing and compute vision and other research fields make much effort on it. But the progress is slowly. At present, although some semi-automatic feature extracting systems has been gone into application, automatic features extracting is still a dream. The scheme of this approach is shown in Fig 2.

Existing old map always can provide useful information for extracting features from images. This kind of prior information can reduce the difficulty of change detection significantly. Especially in GIS database, there exist plentiful information and knowledge. Based on these contents we can design many algorithms to assistant in extracting features from images.

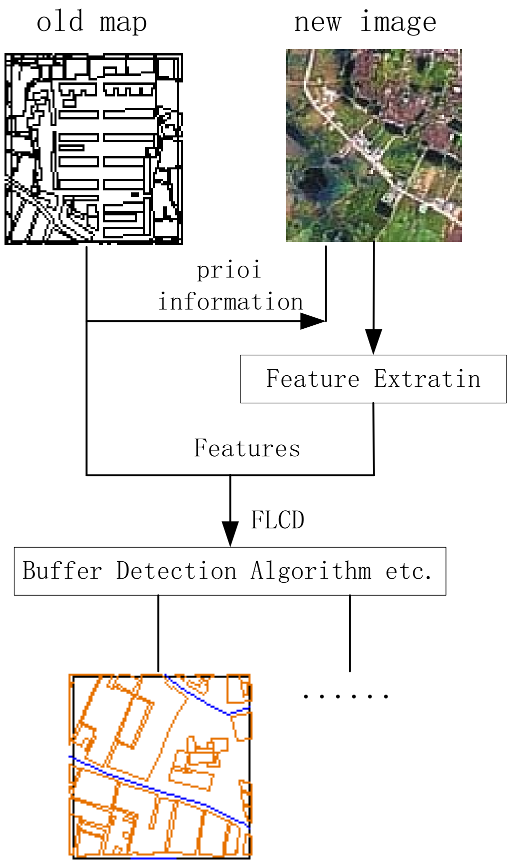

Figure 2. The scheme of change detection between new image and old map

Features extracted from images can be used to detect the changes of old maps. The so-called "buffer detection" algorithm (Haigang Sui, 2002) can be employed in the change detection for features. The main idea of "buffer detection "algorithm is to make buffers for corresponding features in the new image and map by given buffer distance and compute the parts fall into the buffer. If the ratio of these parts to origin feature is larger than given threshold, then this feature is considered changed. The buffer distance can be deduced theoretically.

3.1.3 Change Detection between New/Old Images and Old Map

Indeed, there are too many problems when only using new image to detect the changes of old map. The main problem lies in that we have to extract features only from old image because we have no any other information. However, if existing old image corresponding with old map, the difficulty of change detection can be reduced significantly. Firstly we can compare two images directly using PLCD algorithms. The detection results provide the outline of changes. Then FLCD algorithms can be employed for further change detection. Obviously, this method is the integration of PLCD and FLCD. The scheme of this approach is shown in Fig 3.

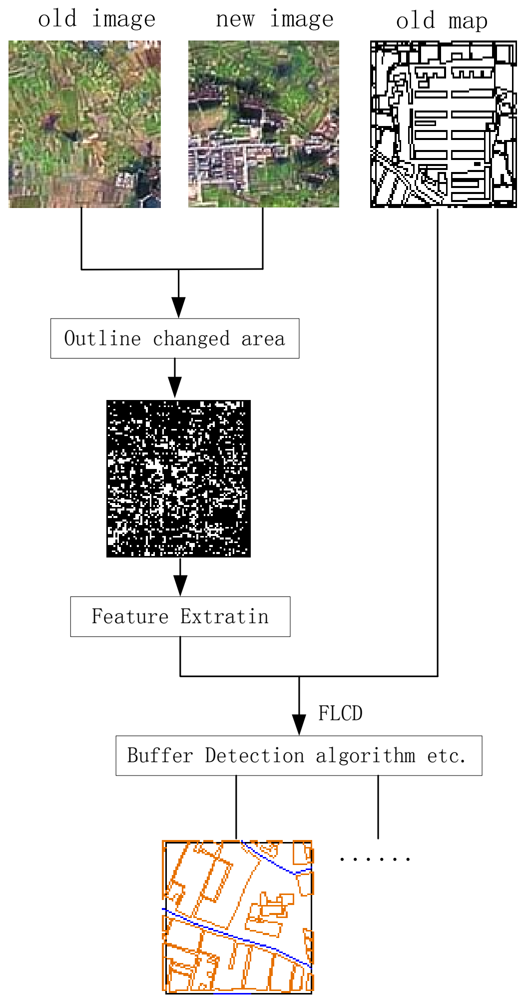

Figure 3. The scheme of change detection between old/new image and old map

3.1.4 Change Detection between Multi-Source Images and Old Map/Image

After the development of thirty years, huge changes occurred for remote sensing systems. We are get remote sensing data with different spatial, spectral and temporal resolution from different remote sensing platforms. These image data formulate a image pyramid, provide user with the earth observation data from coarse to fine resolution, from multi-spectral to hyper-spectral. Multi-sensor, multi-temporal, multi-spectral, multi-resolution has become the main character of current remote sensing platforms. All kinds of remote sensing platforms provide thousands of images every day. However, the data from each sensor only reflects one or several aspects of terrain objects. No any kind of remotely–sensed image provide all information people want. So single image data source for automatic detecting changes for a complete change detection project is always not enough. Integration of multi-source images for change detection is worth to consider and research seriously. Image fusion is valuable techniques to play a role in this issue.

Preliminary results of many researchers show that the combination of two sensors can be combined by image fusion and the information extraction capability can be proved. The algorithms of fusing high-resolution image with multi-spectral image have evolved from traditional methods such as RGB, IHS, PCA pyramid-method to nowadays various new techniques like wavelet-based methods and other techniques. Indeed, using image fusion for multi-sensor images can improve the reliability and quality of change detection, but because image fusion is a new topic, there are still many problems to be solved. The scheme of this approach is shown in Fig4.

3.2 Change Detection Simultaneous with Image Registration

The key problem of change detection simultaneous with image registration is to solve automatic matching. For different data sources, matching element is different. For images, it means homonymous points. For map to image, it means invariant features. Generally speaking, in change detection, we use DLG (Digital Lines Graph) for map, DOM (Digital Ortho Map) for image to detect changes. Sometimes when lack of DLG,DRG (Digital Raster Graph) is also a good substitute. According to different detection data sources, we can classify this approach into the following three categories:

- Change detection between old DEM, DOM and new non-rectification image
- Change detection between old DLG, DRG and new non-rectification image
- Change detection between old DEMs, DOMs and new multi-overlapped photos

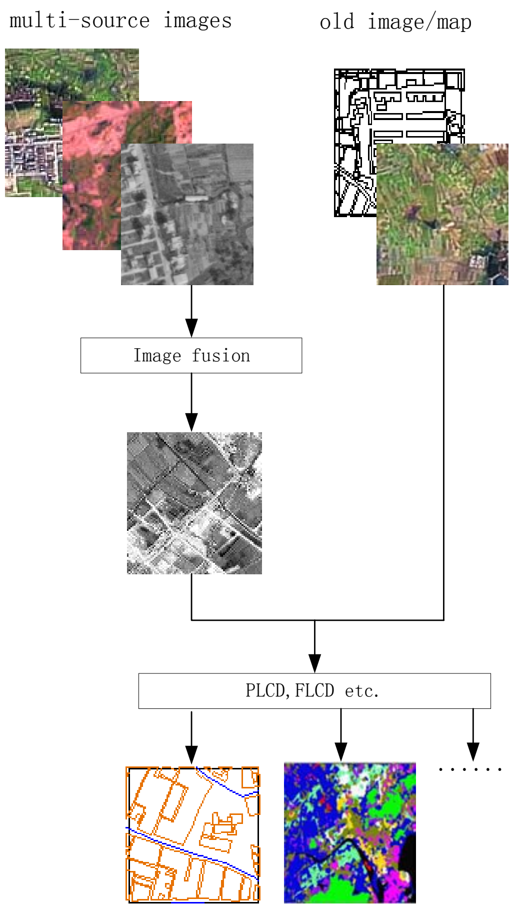

Figure 4. The scheme of change detection between multi-source images and old map/image

3.2.1 Change Detection between Old DEM, DOM and New Image

Two approaches are possible for automatic images registration. The first is rigorous orthorectification (Mayr & Heipke, 1998).Through orthorectification for each image, multi-temporal and multi-source images are co-registered in the ground coordinate system. The approach is rigorous and robust. However, it needs orientation parameters for the sensor in addition to digital elevation model (DEM). If we have the corresponding DEM data with new image and orientation parameters, then the so-called single-photo orthorectification technique can be employed for it.

However, sometimes when lack of these essential data, the second approach that is image-to-image registration is necessary. This approach doesn't require orientation parameters of DEM. But a reference image is needed. We can use old DOM as the reference image. Obviously, automatic finding homonymy points in new and old images is the key problem. It is not a fresh idea to automatic match between images. Multi-scale matching strategy is always employed as an efficient approach. All kinds of automatic matching theory and algorithms including least squares image matching, dynamic planning image matching and so on can be directly of indirectly applied into this research as a good reference. The scheme of this approach is shown in Fig 5.

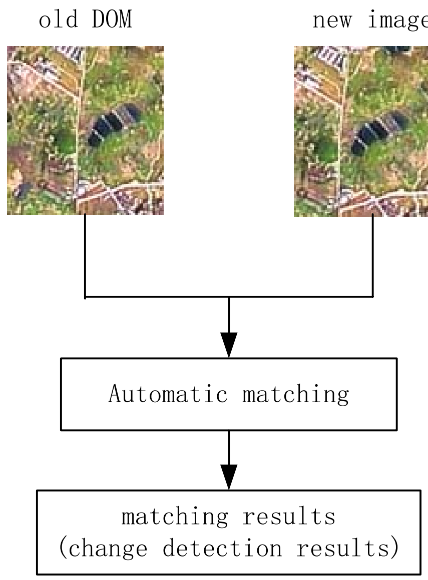

Figure 5. The scheme of change detection between old DEM, DOM and new image

Actually in the procedure of image matching we can find the changed or no-changed pixel(s). If the matching results are very good, then it indicates no change occurs for the participant matching pixel(s). Whereas the bad matching results indicate changes occur. Here, we can distinguish two kinds of changed points: the first is the reliable point and the second is the doubtful point. Reliable points including those changed points (with high reliability) and those no changed points (with low reliability). And doubtful points need to be further processed and confirmed using other algorithms and evidence.

3.2.2 Change Detection between Old DLG , DRG and New Image

Comparing to the approach described in section 3.2.1,this approach is more difficult. Automatic finding invariant feature between DLG,DRG and image is a puzzled and key problem. Preliminary research results show semi-automatic registration based on point feature is a mature method in application but it is not a recommendatory method because of lack of non-shape information. Considering the content of shape information, which is crucial in feature matching, the line based matching and polygon based matching are the priority selection. The scheme of this approach is shown in Fig 6.

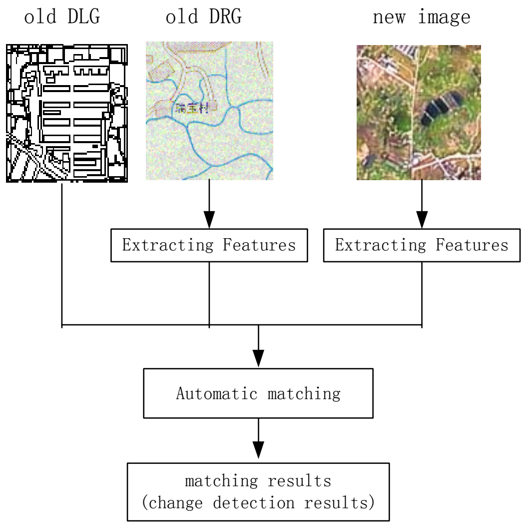

Figure 6. The scheme of change detection between old DLG, DRG and new image

In general, Automatic registration based on features consists of the following key step: Automatic feature extraction from image, such as edge detection, image segmentation and other image processing techniques, feature description using the common feature descriptors including Shape Matrix and so on, similarity assessment, comparing and matching for every feature from DLG and extracted features, rectify new image and post-processing. Obviously, the comparing and matching results indicate the change detection results. This point is same with the description of the previous sections.

3.2.3 3D Change Detection between Old DEMs, DOMs and New Multi-Overlapped Photos

Comparing with above all the change detection, two big differences lie in this approach: one is in this approach multi-overlapped photos are employed and the corresponding algorithms are more complex, another is because multi-overlapped photos cover larger area, the old DEMs,DOMs may be stored in the database. And the searching and comparing scope is enlarged. This sharpens the difficulty of image rectification and change detection.

The first key problem is still to find the matching features between origin DOMs databases and multi-overlapped photos automatically. The matching results, on one hand, are considered as change detection results, on the other hand, are employed for computing the orientation parameters. Using these parameters, the so-called block aerotriangulation by bundle method is introduced for obtaining ground coordinates of every point. Obviously, this approach both involves change detection and 3D reconstruction. It is the most difficult approach in all methods. The scheme of this approach is shown in Fig 7.

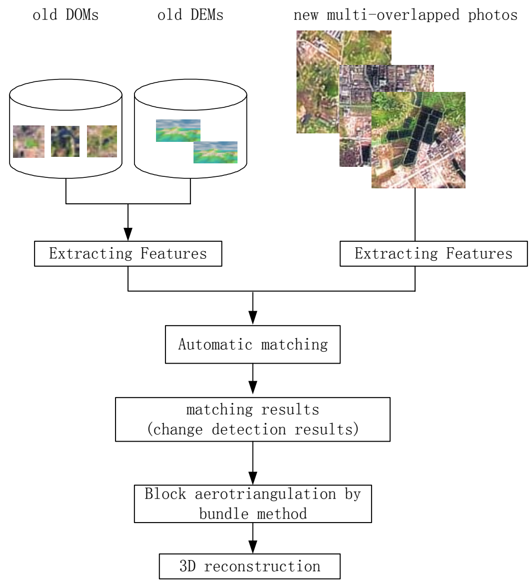

Figure 7. The scheme of 3D change detection old DEMs, DOMs and new multi-overlapped photos

4. CONCLUSIONS

In this paper, the problems and difficulties in automatic change detection were analyzed firstly. We classify change detection into change detection after registration and change detection simultaneous with change detection. From the principle, algorithm and characteristic, every classification is illustrated in detail in the later chapters. It is obvious that the latter is more difficult than the former. Even now we emphasized the importance of the latter because the implementation of them will improve updating efficiency significantly.

Indeed, automatic change detection and updating is really a very difficult problem. But it is especially useful not only for geo-spatial data updating but some special application such as military fields. For geo-spatial data updating, semi-automatic change detection and updating may be the best approach at present.

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