

RESEARCH ON KEY POINTS OF 3D CHANGE DETECTION OF GEOSPATIAL DATABASE

XIA Song ^a, LI Deren ^b

^a Information School, Zhongnan University of Economics and Law, Wuhan, China – xiasongwh@yahoo.com.cn

^b National Laboratory for Information Engineering in Surveying, Mapping & Remote Sensing, Wuhan University, China

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ABSTRACT:

Geospatial data is a dynamic representative form of spatial information on surface of the earth. Facts and reasons on terrain changes are analyzed at first. Changes on the surface of the earth are mainly derived from variations of ground objects which are mostly caused by human activities and natural forces. Model, content and manner for updating and change detection of geospatial data are investigated. The process of updating geospatial data can be regarded as modifying, restoring and improving existing data content in order to acquire current representative form of geospatial data that is in accordance with predefined aim. In this paper, technical framework of 3D change detection on existing DEM, DOM, DLG and new stereo imagery is presented. Difficulties of 3D change detection are investigated, and resurvey or update is the primary issue. Knowledge discovery in databases (KDD) and data mining (DM) aim at extracting valuable knowledge from huge amount of original data, in order to describe past trend and future tendency. The paper presents the thought of bringing the framework of 3D change detection into the whole systematic framework of KDD and DM.

1. INTRODUCTION

As human activities, spatio-temporal variations of environment as well as the interaction of four spheres in the geosystem contribute to the changes of the landscape on the earth surface and its utilizing forms, change detection based on different temporal remote sensing imagery is the key technique for applications of earth-observing system such as surveying resource, monitoring land use and land cover change (LUCC), updating fundamental spatial database et al. And change detection technique is of urgent demands and promising prospect in scientific applications. Change detection and data updating in Geomatics is a new prosperity phase for the combination of remote sensing science, geosystem science, statistics and computer science, and they represent main developing aspect of remote sensing (RS) and geographical information system (GIS).

Generally speaking, change detection is comparing different temporal descriptive information of the same object or region, finding their discrepancy, and acquiring changed information. As for remote sensing, change detection means extracting and describing changed characteristics of interested objects or phenomena based on different temporal observations, quantitatively analyzing and determining differences, and providing foundation for scientific decision. Extracting information of land use and land cover change by remote sensing is a complicated process with interlacement of multiple factors. Precondition of achievements of the process lies that variations of objects should induce variations of radiation which must be greater than radiative variations incurred by other factors such as atmospheric condition change, discrepancy of solar altitude, difference of soil moisture et al. Therefore discrimination of the variations resulting from change of biophysical factors or other interferential factors on radial transmission path is compulsory, and effective change detection method for interested objects is necessary.

D.Lu summarizes and reviews all the major change detection approaches implemented as found in the literature (D.Lu, 2004). They discovered that different algorithms have their own merits and no single approach is optimal and applicable to all cases. On the basis of previous research and applications of change detection, the paper investigates the essential framework of 3D change detection, discusses the sticking points and complicity.

2. TERRAIN CHANGE AND DATA REVISION

Spatial information means not only earth-observing and earth-positioning information acquired by earth observation satellite or navigation satellite, but also the earth's surface information relating to spatial position (Tong Qingxi, 2005). Geospatial data is an important representative means of spatial information, but the data representation is dynamic and has always been changing with the past of time.

2.1 Facts and Reasons

Ramirez attributed change reasons on the earth's surface to two categories: natural forces and human actions (Ramirez, 1998). Natural forces, on one hand, generate abrupt and usually radical changes. For example, a massive tsunami and tremors struck Indonesia and southern Thailand in December, 2004. And subsequent powerful earthquake hit Indonesia in May, 2006. The scale of the damage to the local economy, infrastructure, and administration were unprecedented. On the other hand, natural forces also generate systematic and slow changes which may not be obvious right now but they become obvious with the passing of time. For example, altitude of the Everest has been changing due to continual crustal movement, and the latest announced altitude data was 8844.43m in October, 2005.

Human actions effected on change of the earth's surface are ascribed to artificial factor which may include productive activity, cultural activity, construction work, act of war, etc. For example, explosives are often used with the specific purpose of changing the landscape as part of an engineering project. Human actions may result in two types of changes: predictable and unpredictable.

In most cases, changes of terrain surface result from changes of ground objects which are mostly incurred by human actions. Densely populated or developed regions always have more rapid changes than those unpopulated or undeveloped regions. For the same region, aging rate of the relief map varies with the map scale. As surveying and mapping a relief map need certain cartographic generalization according to the map scale, more details of ground feature are omitted on small-scale map and the omitted feature does not effect on the aging of map. So the larger the relief map's scale, the quicker its aging rate.

Generally speaking, normal use of the relief map will be severely affected when terrain changes on the map sheet are more than 40%, and use of the relief map is rarely affected when the changes are less than 10%. Therefore, to important regions, map revision should be done when change rate exceeds 10% and map revision must be done when change rate exceeds 40% (Pan Shixiang etc, 2003).

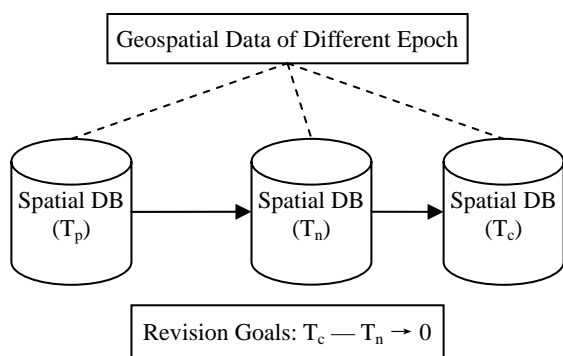


Figure 1. Time Line Model of Spatial Data Revision

2.2 Model and Content

Normally, the longer the period away from last update time, the greater the changes of geographical data and the more complicated the revision task. There are three different epochs to consider from the viewpoint of geographic data revision (Ramirez, 1998): (1) the epoch of the data used in last revision (T_p). (2) the epoch of the data for the current revision (T_n). (3) the current epoch (T_c). The epoch T_c is constantly changing and it is impossible to have geographic data of this epoch. As Figure 1 shows, what can be done is to have geographic data for the epoch T_n such that the difference $T_c - T_n$ will be as close to zero as possible.

In terms of terrain feature represented on relief map, they can be classified into two kinds according to their use value to relief map. Ones are important feature which have essential effects on map interpretation, and their change are also called material change. The others are common feature which have less effects on map interpretation, and their change are regarded as non-material change. On relief maps, necessarily accepted object changes are considered as material changes, and alternatively accepted or rejected object changes are considered as non-

material changes. For example, national boundary, railways, express highways are required on each national basic scale topographic map, and their changes belong to material changes. Little changes of outlines of farmlands or forest lands, lanes or avenues etc, should be ascribed to non-material changes when they do not affect normal use of the relief maps. Main content of change detection and data revision should cover those objects with material changes.

3. TECHNICAL FRAMEWORK OF 3D CHANGE DETECTION

3.1 Technical Framework

Previous approaches of change detection for remotely sensed imagery are mainly constrained to 2D plane in the geographical space, and variations of elevation on the terrain are omitted. Those approaches with remotely sensed data presume that elevation of the terrain has no changes. But this presupposition can not always be true. Investigations on elevation change detection are seldom reported. Gong illustrates the usefulness of DSM and orthophotos generated with digital photogrammetry workstation in the monitoring of changes of gully erosion, water channel incision and coastal salty sand zone displacements (Gong Peng, 2000). Automation degree of this approach is low, and it is primarily researching on the products of orthophotos and DSM artificially. Most commercial software for remotely sensed imagery, such as ERDAS, PCI and ENVI, provide elementary function for 2D change detection and those analysis tools are imperfect for various applications, not to speak of detecting elevation changes. So investigations on 3D change detection system for surface of the earth become urgent and promising.

Li believes that existing 4D products need to be fully exploited in change detection in order to augment predictive knowledge to improve efficiency and automation; image registration and change detection need to be performed synchronously in order to reduce impact of registration error on results; changes of terrain elevation need to be considered for change detection of large scale spatial database (Li Deren, 2003).

3D change detection in geospace can be explicated as follows. Terrain changes should be detected with up-to-date geospatial data such as new aerial imagery or remotely sensed imagery and out-of-date elevation data such as DEM firstly. For terrain changed area, 3D resurvey based on new stereoscopic image should be performed with digital photogrammetry workstation. For terrain unchanged area, DOM or DLG in spatial database can be employed to complete pixel-level or feature-level change detection on 2D plane. After 3D change information of geospatial objects has been obtained, accuracy and reliability of 3D change detection could be evaluated, and timely update of spatial database can be accomplished. Figure 2 shows technical framework of 3D change detection in geospace.

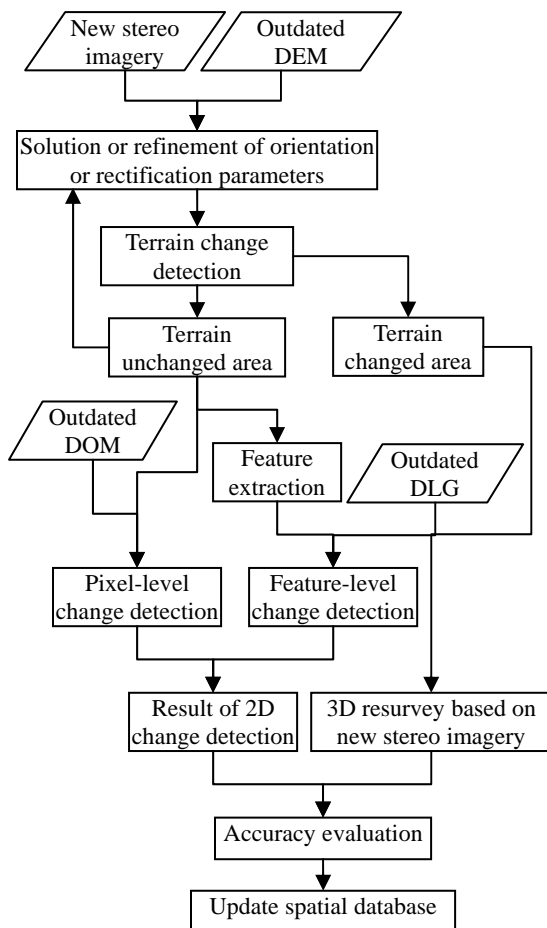


Figure 2. Technical Framework of 3D Change Detection

3.2 Difficulties in 3D Change Detection

Production of geospatial data is a system engineering requiring tremendous investment and complex techniques. It needs not only meeting the demands of analogue relief maps but also measuring up to standards of establishing various GIS database. When providing technical services for users based on fundamental geospatial database, it needs not only meeting the accuracy standards of all walks of life but also satisfying the users' requirement of current situation of data. So every surveying and mapping production administration faces the key issues of establishing rapid and reliable mechanism of change detection and data updating. And several problems should be taken into account.

(1) Resurvey or revision

Update of relief map database mainly means updating ground objects. There are two alternatives to the aim. (a) Resurvey. For a given area, a completely new spatial database is established to replace the old one. Process of this approach is comparatively easy, but it is costly and time consuming. The approach is suitable for establishing a new spatial database for a new region. Or existing geospatial database has to be replaced by a new one, since great changes have taken place in geospatial data or its accuracy can not meet application needs. (b) Revision. It means detecting, identifying, and updating changed parts of spatial data. The approach is of short period and low cost, but the process is complex and it wants excellent change detection techniques. Obviously, the later approach is faster and more popular, but it is on the premise of spatial data registration of

high precision. Choosing resurvey or revision rests with difference of two epochs and changed extent.

(2) Complexity of data

During the course of data updating, an important issue wants considering, i.e. how to utilize existing product data properly to reduce field work and indoor work so as to accelerate the mapping rate. (a) Existing data types (DEM, DOM, DLG, imagery) must be thought over. Different source material decides distinct procedure. Multiple sources can provide plenty of auxiliary information, but it makes the procedure more complex. (b) Regional landform (urban area, hill, upland, alp etc). For example, if updating region belongs to urban area, elementary properties of cities can be utilized. These object properties are characterized by the following traits on satellite imagery (Wen Gongjian etc, 2003). Grey levels change dramatically inside the urban area, while they change mildly around the urban area; City object contains a certain area; In most local regions on the urban imagery, there are two wave crests in orientation histogram of short lines, and the phase difference between two crests approximates to 90° ; In local area on the urban imagery, there are two wave crests in orientation histogram of long lines, and the two crests account for a large proportion in the total histogram. (c) Map scales. In suburban area or mountain area, updating small-scale relief map may utilize new imagery and existing DOM and DEM for registration directly to realize aerial triangulation with no or little control points. But for urban large-scale map revision, existing orthoimage is hardly used. Due to objects' changes, it is difficult for registration of new and old imagery. Furthermore, as a result of different photographic time, dissimilar solar altitude results in dissimilar shade which makes registration more difficult. In the circumstances, DLG is more preferable than imagery (Zhang Zuxun, 2004).

(3) Utilization of control information

General image registration can employ several control points and simple transformation formula. The method is easy and feasible, but it is not strict in theory for all unchanged objects are not fully used for registration. And registration error may result in immediate errors of change detection. Li suggests performing change detection and image registration simultaneously. It can make full use of all unchanged objects as controls and is more accurate and automated (Li Deren, 2003). Zhang believes plenty of linear features on the map can be used as controls for data updating besides traditional GCPs. Applying theory of generalized points, it can wonderfully utilize linear feature as controls for orientation and rectification so as to achieve better overlay of vector and raster (Zhang Zuxun, 2004).

(4) Precision estimation

Precision estimation plays an important role in image classification and change detection. Due to much uncertainty in change detection, systematic estimation is difficult. The same as image classification, current precision estimation of change detection is based on confusion matrix. Different criterion estimates different aspect of detection result. As single criterion can not perfectly express detecting precision, multiple criteria are used for estimation in engineering projects. According to current digital production mode, it is extremely necessary to develop a practical, automatic, semiautomatic or interactive model and software for quality control and precision estimation.

3.3 Experiment on Terrain Change Detection

As terrain change could result in vital change of local geospace,

so its research should be paid much attention to. Approaches of terrain change detection based on VLL matching and orthoimage matching are respectively investigated in our research (Xia Song, 2006). Elementary experimental results show that terrain change could be effectively detected by our approaches.

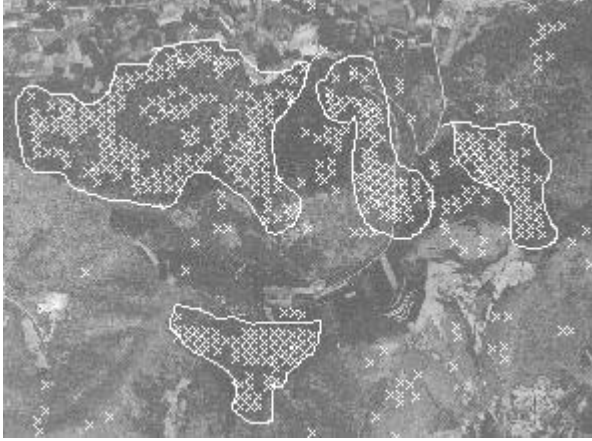


Figure 3. Terrain Changed Area Marked on Imagery

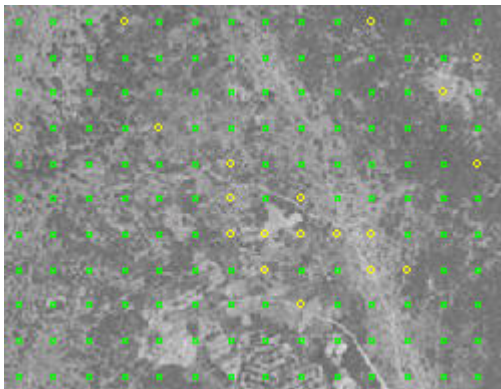


Figure 4. Accuracy Distribution of Change Detection Result

Updated aerial imagery and outdated DEM are employed in the experiments. Updated terrain data (DEM) produced with digital photogrammetric workstation by experienced operators is regarded as standard data to evaluate change detection approaches. Figure 3 shows the detection result, and terrain changed areas are marked on the image. Figure 4 shows accuracy distribution of change detection result. Green squares have marked points with high precision. Yellow circles have marked points with middle precision, and elevations of these points need to be improved by optimized interpolation algorithms.

4. INTEGRATION OF CHANGE DETECTION AND SDM

For geospatial data, the ability of production and transference is far greater than the ability of interpretation and analysis (Li Deren etc, 2006). Spatial data mining (SDM) was proposed and directed at the problem that data are excessive while knowledge is scarce.

3D change detection should make full use of various existing

spatial data and specialized domain information and inference rules in knowledge database to help analysis and decision in order to get optimal results of change detection which could in return be used to update spatial database so as to maintain the current situation of spatial database. The results may also be used as learning resources to generate production rules through inductive method so as to update knowledge database and maintain its dependability. Framework of 3D change detection can be appropriately integrated into the systematic framework of SDM as Figure 5 shows.

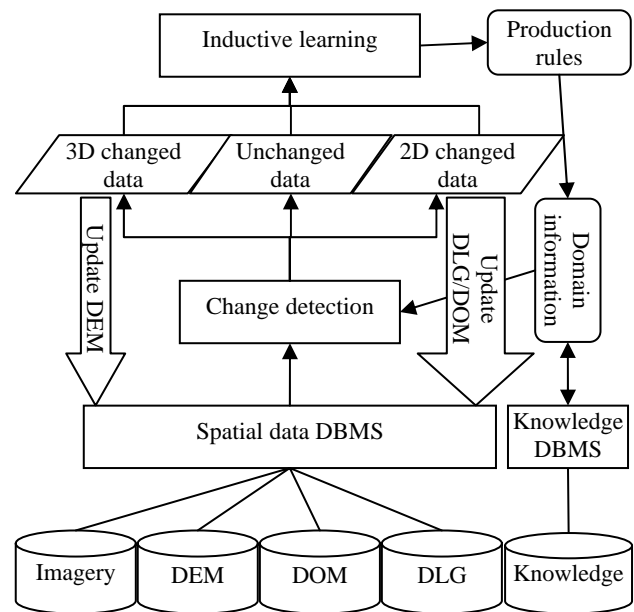


Figure 5. Integration of 3D Change Detection and SDM

As for change detection, there are two kinds of knowledge for use. (a) Context knowledge, i.e. knowledge about the context and objects when the image is acquired. (b) Course knowledge, i.e. knowledge about what knowledge, when to use, how to use, etc. General context knowledge includes: object spectrum characteristic, feature and evolution rules of spatial or temporal distribution, knowledge on models of sensors, knowledge on objective geographical environment, knowledge on imagery, expert's interpretation knowledge, and geosciences auxiliary data.

5. CONCLUSIONS

3D change detection of geospace needs discussing and solving many problems such as whether to resurvey or revision, complexity of source data, utilization of control information, relatively perfect system of quality control and precision estimation, integration of context knowledge and course knowledge etc, among which intelligent image analysis and interpretation is most important.

Significant breakthrough needs combining latest research findings in the fields of cognitive psychology, image understanding, computer vision, artificial intelligence, fuzzy logic etc.

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