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Paper Title

ArcGIS-based Change Detection Analysis Extension to Manage Land Asset Changes in Aramco

Abstract (UC1254)

Detecting land use and feature changes over time is fundamental and necessary for updating GIS base maps and the management of both facilities and natural resources in Saudi Aramco huge land reservations. The extraction of feature changes was traditionally conducted by visual comparison between multi-date images, or between old maps and updated remote sensing images without reliable GIS or engineering accuracy.

In an ongoing mega-project of change detection in Saudi Aramco, a new and efficient methodology is used. The system architecture makes full use of ESRI ArcSDE and ArcObjects capabilities to manage large-size images and integrate many change detection algorithms, including combining temporal images into a color composite for change enhancement and visualization, temporal ratio, and temporal vegetation subtraction. Excluding temporal and multi-source imagery preparation and object-oriented changes' extraction aspects of the system; this paper will mainly discuss the management of large-size temporal imagery of different types in SDE, the creation of image comparison engine, change query, rule-based change analysis, and index-relied change mapping at all scales.

System Requirements

In geospatial domain, land cover change detection is the process of identifying spatial differences in land cover over time. Spatial change detection process usually involves multi-spectral, multi-source, or multi-resolution imagery that have been captured at different times. Traditionally, the change was usually viewed by visual comparison between two multi-date images at small coverage in some imagery systems. Obviously, accurate co-registration of these spatial datasets is a prerequisite step for a reliable change detection procedure.

For a large-scale spatial data-intensive environment, including spatial data warehousing, our customers first need to locate temporal images (for example, between 2000 and 1990) at a specific area of interest (AOI) for further analysis. So, as an important process, the built system should provide a well-organized and easy-search spatial locator for multi-date, multi-sources, and multi-resolution imagery in Saudi Aramco reservation areas across Saudi Arabia.

Generally speaking, the land cover change can be divided into seasonal change and annual change. For example, agricultural lands and deciduous forests change seasonally, but land use changes like deforested areas or newly built towns, which are real changes. Usually seasonal change and annual change are mixed within the same image. In theory, only the real change should be detected, so that two multi-date images of almost same season should be selected to eliminate the effects of seasonal change, if using traditional spectral analysis of imagery. However, in practice, especially when the change detection mission is dealing with high-resolution satellite imagery, this method becomes infeasible because the captured images could be at any seasons in the same area. So, the change detection system should use unique methodologies for identifying spatial differences in land cover over time, rather than purely relying on spectral analysis.

In addition, users are frequently required to randomly monitor large-scale land for certain spatial changes in order to assess and quantify these changes. As an important process, the built system also should provide an easy-query and easy-search spatial locator on different query criteria.

This paper will mainly discuss the efficient management of large-size imagery of different types in ArcSDE for spatial change detection purpose, the creation of server-side and client-side image comparison engine, query, and the accurate mapping of the spatial change.

System Architecture and Workflow

Detecting spatial changes of landuses need practical and reliable processes to handle very complicated spectral or illumination variances in nature, in particular, with large-coverage and high-resolution time-series images. In our mega-project of spatial change detection in Saudi Aramco, a new and efficient methodology is implemented (Figure 1).

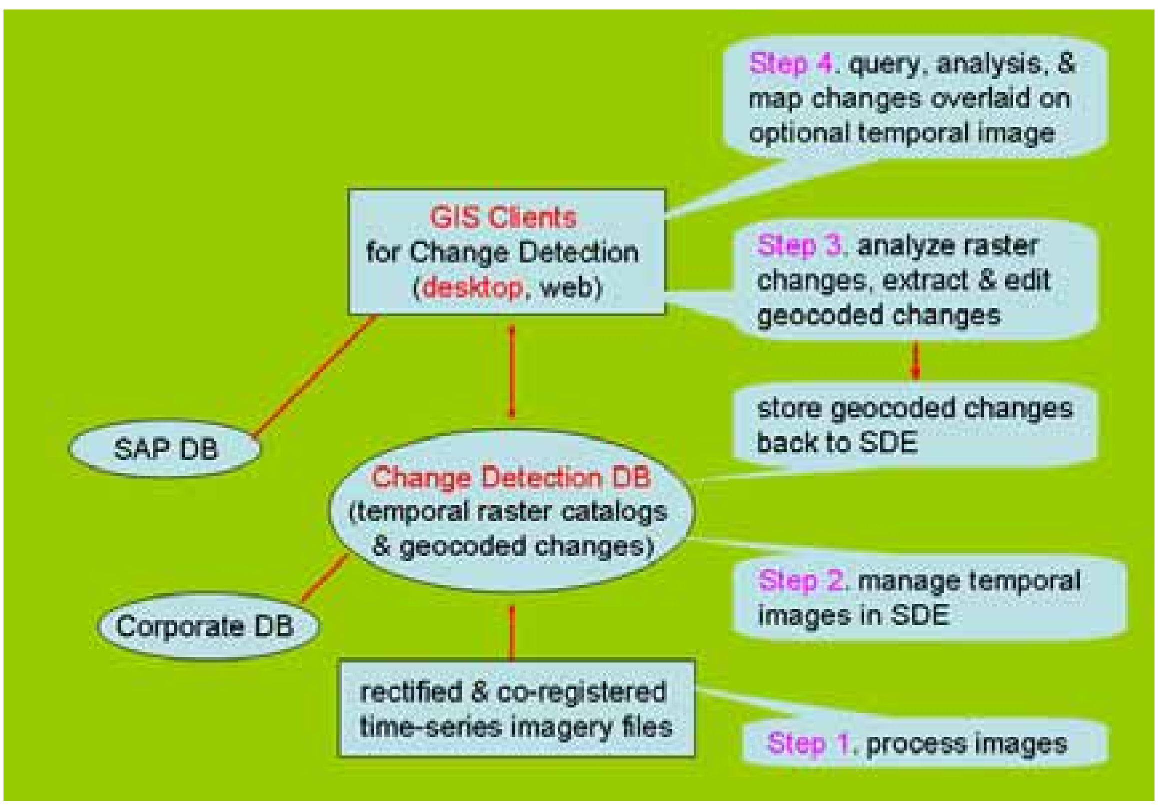

Figure 1 Change Detection Workflow and System Architecture

The system architecture makes full use of powerful spatial engine and GIS extensible capabilities to manage large-size temporal images (Spot 5, Ikonos, QuickBird, airphoto) for customers to build change enhancement from temporal images and to do other analysis, including querying and searching spatial changes, when needed. Considering that this is very large system, the paper will mainly discuss the change detection extension for desktop ArcGIS client and storage strategy in spatial engine, and will exclude discussion on imagery preparation (spatial rectification and co-registration) with LPS, object-oriented extraction with Definiens eCognition, the built-in change detection engine in ArcGIS Server for web-based change detection application, and the customized change detection for SAP.

Management of Multi-date and Multi-source Imagery

In practice, it is first step for customers to find out temporal images in their Area of Interest (AOI) for identifying spatial change. Obviously, it is not feasible for users to manually find AOI images from up to NN TB image file folder(s). Fortunately, raster catalog(s) in ESRI ArcSDE can be used to efficiently and conveniently organize massive and large-scale multiple-source and multi-date images for such kind of purposes.

Before organizing temporal images in change detection database, it is necessary to rectify temporal images first in order to minimize time-series imagery displacements and misalignments (Zhang, L., 2005). After airphotos, IKONOS, QuickBird, and SPOT 5 are geo-rectified and co-registered with GCP and other references, same kind of images with same year attribute are color-balanced and mosaiced into a catalog of temporal imagery, for example, SPOT5-2004, IKONOS-2005, and QuckBird-2006. And then, the temporal mosaiced image is reprojected and divided into regular tiles, which are based on same well-designed spatial coverage with local datum and projection. Those same-year imagery tiles will be managed in a temporal raster catalog with loss compression of JPEG2000 (50% quality compared to pre-loaded imagery). In temporal raster catalogs, table schema at least contains tilename, collecting-year, vendor, and compression-rate. Here, it is worth to note that it is unnecessary to keep spectral values of the managed imagery tiles unchanged.

The change detection extension or engine provides powerful capabilities of spatial query, which is based on the temporal raster catalogs. The users can use user-defined AOI (graphics, shapefile, feature class, etc) to easily find out what they are interested in for change enhancement over time and comparing visualization (Figure 2).

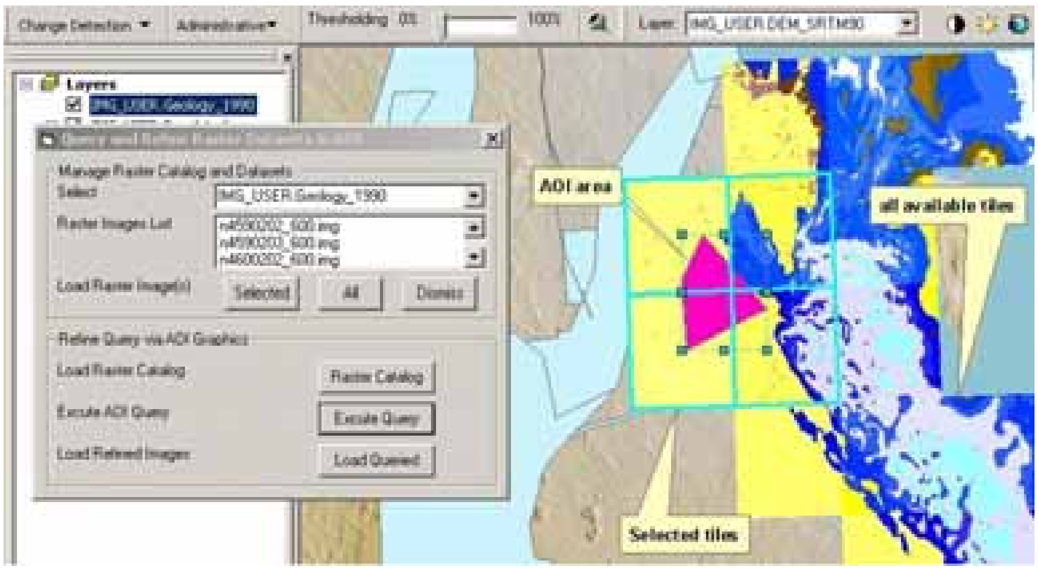

Figure 2 Search AOI Multi-date Images Stored in ArcSDE 9

Identify and Query Changes over Time

The spatial feature change over time can be detected and extracted through pixel-based algorithms (monochrome differencing, thresholding, and color composite) or object-oriented temporal imagery classification approaches in GIS and remote sensing.

In fact, in monochrome images, there is not much hope for pixel-based change detection algorithms that are invariant or insensitive to illumination changes, as only signature of a scene change is an intensity change (which also occurs as the illumination changes). Image content analysis is possible, as is the use of illumination invariant properties, such as monochrome image edge positions and thresholding [1, 2]. However, real world scenes are generally colorful, and detection of changes based on changes in color imagery obviously is straightforward.

So, among these methods, the temporal color composite image is mainly used as spectral bands for change extraction in our system, which ensures that the algorithm is insensitive to spectral changes and illumination brightness over time. This color composite image can be created from multi-date co-registered images, such as relatively-earlier T1-image and relatively-later T2-image (Figure 3a, 3b).

Figure 3a Imagery of 2004 (T1)

Figure 3b Imagery of 2005 (T2)

With either pixel-based or object-oriented classification in remote sensing, its cost increases with the number of spectral bands in multispectral space. For classifiers like the parallelepiped and minimum distance procedures, this is linear increase with bands; however, for maximum likehood classification (most preferred), the cost increases with bands is quadratic. Therefore it is sensible economically to ensure that no more bands than necessary are utilized, that is, band selection, before performing a classification. In addition, it is worth to realize that random band selection can not be performed indiscriminately. The method must be devised that allow the relative worth of bands accessed in a rigorous way.

In our change detection system, temporal spatial change is efficiently enhanced by integrating two temporal images into a color composite, which consists of band 1 (Red) from band 1 in T2-image and band 2 (Green) & band 3 (Blue) from band 2 & 3 in T1-image. From the composite image, most real emerging objects can be easily identifying in red color, and disappearing objects are in cyan color. With this temporal composite image, both emerging objects and disappeared objects can be segmented and extracted through using either automatic object-oriented classification in remote sensing [3] or manually digitizing in GIS.

It is worth to note that some grass lands and deciduous forests are also in red color. In fact, they change seasonally, not real feature change annually. In practice, customers want to discriminate them from real annual change (Figure 4).

Figure 4 Emerging Objects in Red and Disappearing Ones in Cyan

Geocoding spatial change over time is a very important process for this mega-system, so that it can assure customers to conveniently query and report spatial change in Aramco reservation areas, whenever needed (Figure 5).

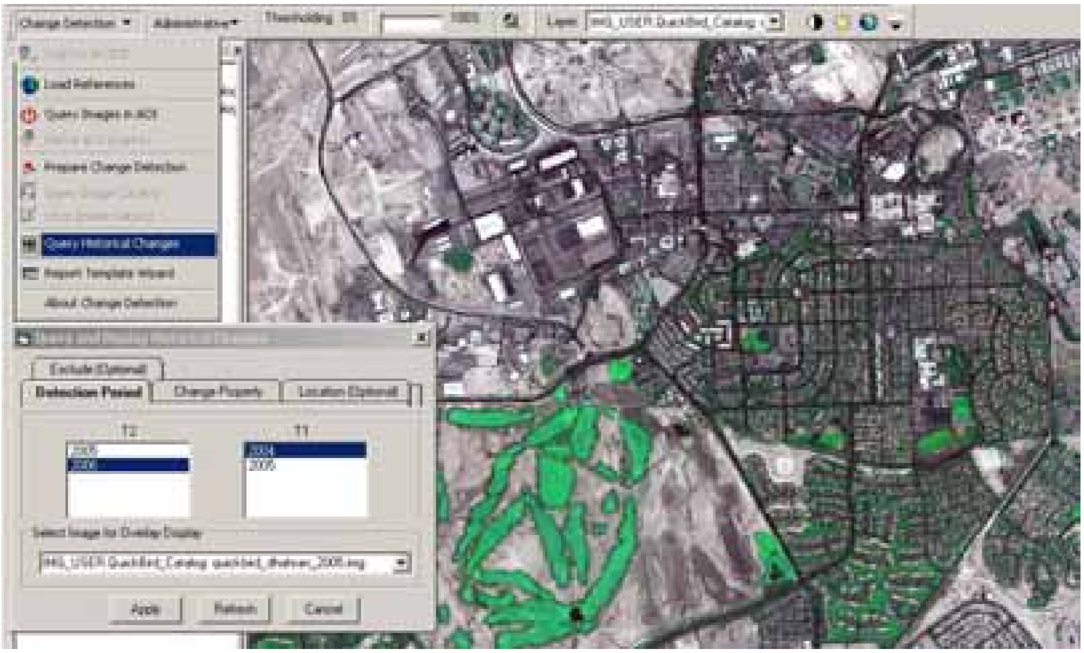

Figure 5 Query Spatial Changes over Time

Temporal feature classes of spatial change can be used as a reference for geocoding process. Geocoding spatial change fully uses well-defined temporal change table schema, which consists of time-beginning, time-ending, location-name (community, facility), linear-measurement (pipeline, road), change-property (emerging, disappeared), and /or, change-type (real annual change, non-real seasonal change). So, spatial change geocoding table can be easily updated and expended at any time without affecting clients' use.

Change Analysis for Priority Management

Change analysis is mainly used for creating priority levels of Aramco landuse. The system provides rule-based analysis functionalities to find out potential changes excluding certain changes under some defined criteria. Its goals and objectives were identified for priority management areas of Aramco conversations through change data analyzes, including priority model runs and other standard methods. These change data analysis helps the Partnership determine the estimated land uses or land covers required to achieve long-term sustainable management in Aramco reservations, as well as where suggested reductions in land use would have to occur to achieve the desired effect.

The Change Detection also fully makes use of mapping customization capabilities within ArcMap allowing the end users conveniently to generate change maps at all scales, which are based on index feature class and overlay on optional temporal image.

Conclusions

Change detection is one of the most common applications using satellite image and airphoto data. The accurate detection and efficient analysis of changes between time-series images are very complicated processes for users rapidly to move from massive image to meaningful information to decision-making, including accurate processing of temporal images, synoptic and compared views at varied spatial and temporal scales, and searching changes at large coverage, which can be overwhelming even for the most advanced users.

Implementation of our change detection system ensures that users can easily find out temporal images in large coverage from well-managed temporal raster catalog database in ArcSDE, and efficiently detect feature differences over time in order to represent the real business processes, including color image of temporal composite, differencing and thresholding, extracting changes, and geocoding changes. The system provides fully flexible approaches, which are insensitive to the illumination brightness and spectral change over time in real world scenes, to allow users easily differentiating and tracking changes, which is based on varied query criteria for searching spatial changes over time. The change detection system also allows end users easily to do rule-based change analysis and generate index-relied change maps at all scales.

References

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3. Definiens, 2006, User Guide for Developer 6 and User Guide for Analyst 6, DEFINIENS Enterprise Image Intelligence Suite