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# Change Detection Techniques using Optical Remote Sensing: A Survey

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**Abstract**

Environmental planning and management requires continues updating of map to be significant. This has even become curtail in the rapid development and dynamism of urban areas. The advent of GIS has made the regular update of maps easer with the several images and data acquired by many remote sensors covering the earth today. Changes occur in the environment and urban areas can be historically and temporally monitored and traced using various change detection techniques. The effectiveness of these techniques however depends on some factors. Such factors include specific application, accuracy, time and cost. In this paper an evaluation of some change detection techniques/ algorithm was made to identify their potential, accuracy and effectiveness. The evaluation was carried out through image classification for efficient land use management.

***Keywords:*** Satellite images; remote sensing; map updating; change detection; digital image processing.

## 1. Introduction

### *1.1. General*

The world is rich of geographic information which can be presented in form of paper maps. It is well known that more maps have become available in digital forms. Computer map updating is an important task that has been presented for more than three decades. The necessity of up-to-date urban maps is worldwide desirable in countries where the urban development is appreciated.

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Manual map updating is a time and cost-consuming process. This makes automatic or semi-automatic maps updating an attractive process requested for satellite imagery and processing techniques.

There are many types of satellites currently have been launched in space, optical or microwave sensors, active or passive, and have high or low resolution. Satellite images provide a reliable source of data for the characterization of urban land use/cover types and their change over space and time. Change detection is the process of identifying differences in the state of an object or phenomenon. It is carried out by analyzing a pair of images acquired on the same geographical area at different times. Thus, many techniques of change detection have been developed; using different satellite images data. This paper is a comprehensive survey of methods that used in literature as change detection becomes an active topic and new techniques are being developed.

In this paper, several change detection keys were presented. The data used in this study described in section 2. Section 3 contains the steps of change detection techniques. The preprocessing of remote sensing images is covered in section 4. The review of change detection techniques are categories into three groups, these groups are summarize and reported in section 5. Section 6 concluded the results of this survey.

### *1.2. Data used in change detection*

Satellite remote sensing is the main data used in change detection. It provides a consistent source for the characterization of urban land use/ cover types and their change over space and time. Basically, there are two types of satellite data set used to detect change [12]. Firstly, comparing two satellite remote sensing images taken in different times (bi-temporal data), one image in time1 and the other in time2. Secondly, comparing one remote sensing image (of current or recent year), to an existing land use base map (image in time2 and map in time1).

### *1.3. Change detection steps*

There are several steps involved for implementation of change detection [11]. These steps are: i) identify the nature of the change detection problem including the region, time and class of interest [3]. Other examples of this step include [31] and [9] who studied changes in houses, forest and linear features, ii) consideration of significance when performing change detection iii) remotely sensed data processing (including image preprocessing, change detection algorithm and image classification) to extract change information andiv) accuracy assessment.

The problem definition is an important step, and extended time duration is helpful in detecting the change in urban area while period of one year is critical in forest change. Other considerations include remote sensing system and environment characteristics. The remote sensing system considerations (temporal, spatial, spectral and radiometric resolution) have an important impact on the success of the change detection, while the environment characteristics include atmospheric conditions, soil moisture and phonological characteristics [29].

### *1.4. Image pre-processing*

The preprocessing of remotely sensed data includes geometric rectification and image registration, radiometric normalization and atmospheric correction, and topographic correction if the study area is a mountainous region. To get a correct measurement and precise localization for features; image must rectify geometrically. The accuracy required for national land use change program is that the root mean square should be from 1 to 2.5 pixels. Image registration is important to minimize the rectification error. A second order polynomial model is commonly used to register the uncorrected image to a rectified one using ground control points (GCPs). The error measured is greater than 50% if there is a misregistration of only one pixel [26]. On the other hand, the geometric rectification and image registration are complementary to each other. Radiometric normalization is necessary as change detection is highly dependent on accurate geometric and radiometric correction (change detection is depend on spectral analysis) and the commonly used method is image regression. Atmospheric correction is required when images are taken in different time of the day and reason. According to reference [5], the presence of haze in the atmosphere masks real change which requiring atmospheric correction.

## 2. Change detection techniques survey

Many remote sensing data are available include landsat MSS, TM, SPOT, AVHRR, Ikonos, QuickBird, radar, and many other satellite images as well as aerial photographs. Most mapping from satellite imagery in the past has been achieved using data from Landsat and SPOT (low resolution sensors). In other word, Landsat MSS, TM and SPOT are commonly used but for map of small scale. High resolution images data are more suitable as it provide a huge amount of details with low cost. High resolution satellite images can also be used to detect changes in topographic maps at scales from 1:6000 to 1:10,000 which had not been found by traditional change detection methods [10]. Some researchers have compared between several type of sensors (optical and microwave), (high and low resolution). Thus, they evaluated the potential of both panchromatic and multi-spectral satellite imagery for updating large scale map and identification of change occurring.

Many researchers, who focus in map updating, used different classification and change detection techniques, for several applications. The areas of these applications include: land use and land cover, forest, agriculture, wetland change, environmental planning and decision support, urban management, and others. In recent years researchers have started using high spatial resolution images, like QuickBird and Ikonos, to investigate land used change in urban areas but this unlike Spot images is limited because of their high cost, especially in china. Spot has become the main remote sensing data used in China due to its advantage in both spatial resolution (2.5m) and coverage [12]. Detecting changes using satellite remote sensing data can be done using several techniques, these techniques can be categorizes into three types:

### *2.1 First Category*

In this category as shown in table1, change can be detected using simple techniques such as image differencing, image regression, image rationing, change vector analysis (CVA), vegetation index differencing (NDVI as an example) and background subtraction. These techniques are simple and easy to implement [4]. The image differencing is the most commonly used method for forest and agriculture area [1] rather than background subtraction which provide poor change detection capability.

Reference [27] examined the change in vegetation area using normalize differential vegetation index (NDVI). As mentioned previously, he found that an error greater than 50% of the actual differences in the NDVI as measured by the semi-variance, was caused by a miss-registration of only one pixel. To achieve an error of only l0%, registration accuracies of 0.2 pixels or less are required. Reference [4] have examined the utility of image differencing, image rationing, image regression and change vector analysis to assess their effectiveness of detecting change in land use/cover. They found that change vector analysis is the most accurate one for capturing and identifying changes using bands 3 and 4 of Landsat TM imagery. A large overall accuracy of 75.25 to 75.55% change vector analysis is capable by utilizing any number of bands in change detection.

Reference [8] studied change using background subtraction techniques and they avoided the segmentation errors by modification of the existing algorithm. Reference [9] determined linear features which are significantly differ from their surrounding using the change vector analysis. This method varies significantly from the traditional edge detection technique, as it enhances the multi-spectral differences, determines false changes due to miss-registration. Also, it avoids many more edge features which represent only change in brightness. In this category two aspects are critical for the change detection results, selecting suitable image bands or vegetation indices and selecting suitable thresholds to identify the changed areas. The disadvantages of this category are its limitation of less detail in change (matrix information) and its results in low accuracy comparing to other techniques.

**Table 1:** Simple Techniques of Change detection techniques

| Category | Techniques | Advantages | Disadvantages | Application |
|---|---|---|---|---|
| First Category of Change Detection Techniques | Image Differencing | Simple, easy to implement | Cannot Provide Matrix Information | Forest [19] |
| | Image Regression | Take atmosphere condition affect in concern [22] | Depend on the radiometric condition of reference image | Land use [4] |
| | Image Rationing | Can calibrated | Cannot Provide Matrix Information | Forest and land use [4] |
| | Vegetation Index Differencing (NDVI) | Reduce the topographic effect | Change result concern noise | Vegetation [27] |
| | Background Subtraction | | Cannot Provide Matrix Information | Forest [21] and [8] |
| | Change Vector Analysis (CVA) | can provide change details information | Change lines are difficult to identify | Land cover and other [9] |

### *2.2 Second category*

The second category include unsupervised change detection, post classification comparison, neural networks, spectral and temporal combined analysis, principle component analysis (PCA), Tasselled cap (KT), Gramm-schmidt (GS) and Chi-square transformation (see table 2). The last four methods have the same disadvantage as the simple category in that they cannot provide change information. In addition to provide a matrix of change information, the rest of methods reduce external effects of atmospheric and environmental differences between multi-temporal images. The spectral temporal combined analysis, Gramm-schmidt and Chi-square transformation methods are rarely used, while neural network method is being frequently used, currently, for land cover change [16,25] and [23,24].

**Table 2:** Change detection techniques, Second category

| **Category** | **Techniques** | **Advantages** | **Disadvantages** | **Application** |
|---|---|---|---|---|
| Second Category (techniques based on classification and mathematical modeling) | Unsupervised Change Detection | Provide change information matrix | Change result depend on the number of clusters | Land cover [23] |
| | Post Classification Comparison | Generate change information matrix | Accuracy depend on classification skill | Forest [32] |
| | Principle Component Analysis (PCA) | Reduce data redundancy | Change result depend on visual assessment | Land cover and forest [12] and[2] |
| | Tasselled Cap (KT) | Develop spectral information | Scene independent | |
| | Gramm-Schmidt (GS) | Difficult to extract information | Complexity | Forest monitoring [6] |
| | Chi-Square Transformation | Used more bands | Time Consuming | Urban change [20] |
| | Spectral Temporal Combined Analysis | Simple and time saving | Extract Change statistically | Environment and forest [22] |
| | Neural Networks | Completely automatics | Using single band give accurate result than using multispectral radiance | vegetation [24] |

Although best result in forest change can be obtained using both Gramm-Schmidt (GS) and PCA techniques, the latter is better than the former [6]. The integration of supervised classification and expert system techniques were used for change detection and map updating of forest located in Grand Lake in Labrador. According to [32], this integration was found to be helpful as a tool for interpretation purpose. Reference [23] proposed new method by combining unsupervised change detection techniques with neural networks method to model the spatial correlation between neighboring pixels of the difference image. Reference [24] again modified the unsupervised context-sensitive technique by using self-organizing feature map neural network. Reference [7] found that the classification accuracy of landsat-5 TM is better compared to ERS1, PHARUS and Ikonos. The accuracy of change detection can improve by combining simple techniques with the second category, such as KT with PCA and NDVI [2]. Combining unsupervised classification and change vector analysis (CVA) technique and use of morphological filters provide most effective result [17].

To improve the accuracy of change detection result, reference [14] proposed a new method by combining three indicators; vegetation indices, surface temperature and spatial structure. In the second category techniques, the Tasselled Cap (KT) method is the most useful with the advantage of that the coefficients are independent of the image scenes.

**Table 3:** Change detection techniques, Third category

| Category | Techniques | Advantages | Disadvantages | Application |
|---|---|---|---|---|
| Third category (not commonly used techniques) | linear spectral mixture model (LSMA) | Give accurate result but it consider as advanced image processing | Focus on image processing rather than change detection method | Forest and land cover [13] |
| | generalized linear model | Give accurate result and it Characterize as a high level of thematic accuracy | It need more computer skill and not commonly used because it consider as a new method | Land cover change [18] |
| | change curves approach | | | Vegetation change [15] |
| | curve theorem based approach | | | Land cover change [31] |
| | knowledge-based vision system | | | Monitor urban development [28] |
| | ellipsoidal change detection technique | | | Forest and land cover [30] |

### *2.3 Third category*

The last category of change detection techniques include new techniques that are not commonly in used (see table 3). Such techniques include change curves approach [15], curve theorem based approach [31], linear spectral mixture model (LSMA) [13], generalized linear model [18], knowledge-based vision system [28], and the ellipsoidal change detection technique [30]. LSMA is the most commonly used method among others. In this approach, the change is detected by transforming the image reflection value to physical fraction and by comparing the fraction of two images. It is a precise but complex method and time consuming.

## 3. Conclusion and Recommendation

Digital change detection is affected by spatial, spectral, temporal and radiometric constraints. Due to possibility of many change detection methods, the selection of a suitable method or technique for a given problem is important, but not easy. The rates of most urban growth are located in the developing countries where most land use/ cover changes are from forest and cultivated land to urban and built up area. Map revision is usually done by integration of remote sensing and geographic information system. The use of high resolution data faces two problems: the first one is the difficulty of classification process and the second is the complexity of urban areas to be mapped [3]. Generally, the use of multi sensor data (image fusion) gives best result in change detection, but limited by difficulties in image processing (e.g. the need of large amount of training sample data for the classification process). The other limitations are choosing of appropriate change detection algorithm and difficulties in data availability for long time period of change detection (especially AVHRR data). Different researchers have different conclusions about the change detection techniques due to the impact of different factors on the effectiveness and accuracy of the technique. The Accuracy of change detection results depends on the precise image pre-processing (between multi temporal images), classification methods, change detection algorithm used and ground truth data.

The scientific literature showed that there are some difficulties to perform digital change detection procedure. A variety of digital change detection techniques have been developed over the last decades. The techniques which look for object based gives accurate results with matrix of change information. This is represented clearly in the second category, with saving time and having a change boundary. Thus, the recommendation is to develop the second category and giving more attention to neural networks technique.

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