

Multi-Temporal Satellite Imagery for Urban Expansion Assessment at Sharjah City /UAE

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Abstract. Change detection is the process of identifying differences in land cover over time. As human and natural forces continue to alter the landscape, it is important to develop monitoring methods to assess and quantify these changes. Recent advances in satellite imagery, in terms of improved spatial and temporal resolutions, are allowing for efficient identification of change patterns and the prediction of areas of growth. Sharjah is the third largest and most populous city in the United Arab Emirates (UAE). It is located along the northern coast of the Persian Gulf on the Arabian Peninsula. After the discovery of oil and its export in the last four decades at UAE, it has experienced very rapid growth in industry, economy and population. The main purpose of this study is to detect urban development in Sharjah city by detecting and registering linear features in multi-temporal Landsat images. This paper used linear features for image registration that were chosen since they can be reliably extracted from imagery with significantly different geometric and radiometric properties. Derived edges from the registered images are used as the basis for change detection. Image registration and pixel-pixel subtraction has been implemented using multi-temporal Landsat images for Sharjah City. Straight-line segments have been used for accurate co-registration as well as main element for a reliable change detection procedure. Results illustrate that highest range of growth that represented by linear features (building and roads) have been accrued during 1976 – 1987 and stand for 36.24 % of the total urban features inside Sharjah city. Moreover, result shows that since 1976 to 2010, the cumulative urban expansion inside Sharjah city is 71.9 %.

1. Introduction

The demand for up-to-date geographic data is increasing due to fast changes to the landscape that are taking place as a result of nature and/or human actions. Such changes have to be accurately and reliably inventoried to fully understand the physical and human processes at work [1]. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times [2]. It involves the ability to quantify changes using multi-resolution, multi-spectral, and/or multi-source imagery captured at different times. Traditional change detection studies are based on visual/manual comparison of temporal datasets (such as satellite scenes, aerial images, maps, etc.). However, the huge flux of imagery that is being captured by an ever increasing number of earth observing satellites necessitates the development of automatic, reliable, and fast change detection techniques. Such techniques are essential to reduce the high cost associated with spatial data updating activities. Several change detection methods have been developed and reported in the literature [2],



[3],[4] and [5]. These procedures are based on image subtraction, image ratio, change vector analysis, principle component analysis, neural network, or morphological mathematics.

The main purpose of this study is to detect urban development in Sharjah city by detecting and registering linear features in multi-temporal Landsat images. This paper used a registration methodology that is based on the Modified Iterated Hough Transform (MIHT) [6], [7] and [8] for simultaneously estimating the parameters of the registration transformation function while establishing correspondence between conjugate straight-line segments in an image pair. Derived edges from the registered images are used as the basis for change detection. Image registration and pixel–pixel subtraction has been implement using multi- temporal Landsat images for Sharjah City.

2. Study Area

The city of Sharjah, United Arab Emirates (UAE) is located along the northern coast of the Persian Gulf on the Arabian Peninsula with a central coordinate of 25.3° N 55.5° E , Figure 1(a), (b) and (c) shows in sequence UAE map , Landsat image of Sharjah city and the study area within Sharjah city.

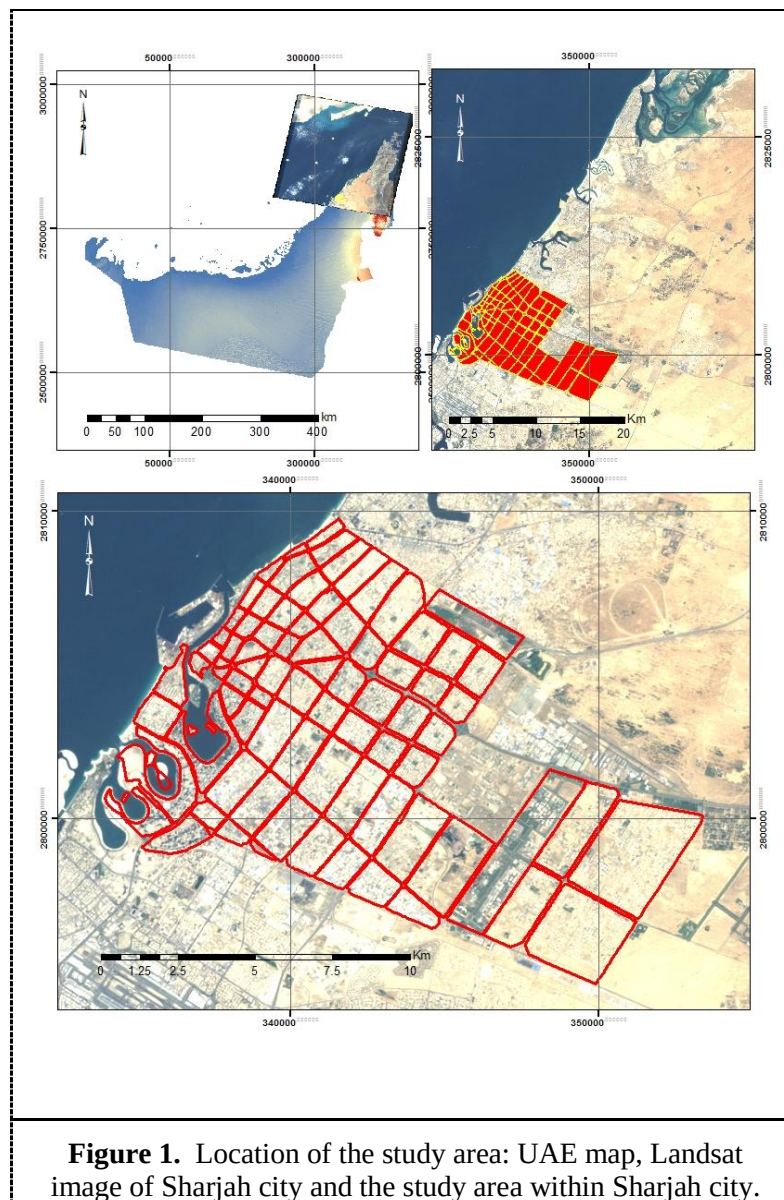


Figure 1. Location of the study area: UAE map, Landsat image of Sharjah city and the study area within Sharjah city.

Sharjah City is the capital and largest city in Emirates of Sharjah located in a dry hot region, with daily high temperatures of 24-42°C and daily main temperature of 18-34°C. The rainy month is typically December to February, with average rainfall of approximately 100 mm/year. The rainfall in dry years doesn't generally exceed 40 mm/year and 200mm/year in heavy rain years.

3. Geospatial Data

The data used in this research include diversity of satellite images with different radiometric and geometric resolution captured in different years. These data will be used for image registration and change detection. Table 1 lists the source of each image including capturing data and the spatial resolution in meters. Figure 2-a shows sample of the Landsat images for the study area for years 1976 and 2000.

Table 1. Landsat images captured at various years.

Satellite	Year	Resolution
Landsat Multispectral Scanner (MSS)	1976	79 m
Landsat Thematic Mapper (TM)	1987	60 m
Landsat Thematic Mapper (TM)	2000	30 m
Landsat Thematic Mapper (TM)	2007	30 m
Landsat Enhanced Thematic Mapper (ETM)	2010	15 m

4. Methodology

In this paper linear feature, image registration and pixel-pixel subtraction has been implementing using Landsat images that have different spatial and temporal resolution. Linear features (straight-line segments) have high semantics and can be reliably extracted from the images. These linear features (streets and buildings in urban areas) were used as the base for change detection. Research has been conducted using multi-temporal imagery over the city of Sharjah. All images have been registered to the Landsat image from 2010. Interest and well distributed points (main intersections and corners of buildings) have been manually digitized in these images to perform the registration process where 10 - 15 points (end points of the linear Feature) have been used to drive the transformation parameters needed for the image registration. It has to be mentioned that accurate registration of multi-temporal imagery can be considered as the most important component of an accurate and reliable change detection procedure, [5].

Having established the transformation function between the images, the input image can be resampled into the reference frame associated with the reference image, Figure 2-a shows an example of Landsat clipped image after image registration and resampling process. The resampling is followed by applying canny edge detection and majority filter to both images. Then, the resulting images are subtracted to produce a change image, which is enhanced by re-application of the majority filter. Section 5 will discuss the theory and principle of the image registration process. Change detection criteria and stages will be discussed in section 6.

5. Image Registration Paradigm

An image registration process aims at combining data and/or information from multiple sensors in order to achieve improved accuracies and better inference about the environment than could be attained through the use of a single sensor. An effective automated image registration methodology must deal with four issues; namely registration primitives, transformation function, similarity measure, and matching strategy

To carry out the registration process, a decision has to be made regarding the choice of the appropriate primitives (for example, distinct points, linear features, or homogeneous regions). In this research, straight-line segments have been used as the registration primitives, Figure 1.

The second issue in a registration procedure is concerned with establishing the transformation function that mathematically describes the mapping function between the imagery in question. In other words, given a pair of images, *reference and input images*, the transformation function attempts to properly overlay these images. Habib et al, 2001a, 2001b showed that affine transformation, Equation 1, could be used as the registration transformation function for imagery captured by satellite imaging systems with narrow angular field of view over relatively flat terrain as compared to the flying height.

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} a_0 \\ b_0 \end{bmatrix} + \begin{bmatrix} a_1 & a_2 \\ b_1 & b_2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \quad (1)$$

Where: (x, y) Denotes the coordinates of a point in the reference image, and

(x', y') Denotes the coordinates of the conjugate point in the input image.

The next step in the registration paradigm is the selection of the similarity measure, which mathematically describes the necessary constraints for ensuring the correspondence of conjugate primitives. The similarity measure formulation depends on the selected registration primitives and their respective attributes. In this work, the registration primitives, straight-lines, will be represented by their end points, which need not be conjugate.

Let's assume that a line segment **A** in the reference image corresponds to the line segment **B** in the input image. The similarity measure should mathematically describe the fact that the line segment **A** will coincide with the corresponding line segment **B** after applying the transformation function relating the reference and input images. Such a measure can be derived by forcing the normal distances between the end points of a line segment in the reference image, after applying the transformation function, and the corresponding line segment in the input image to be zero. Equation 2 mathematically describes such a constraint for one of the end points of the line segment in the reference image.

$$x'_1 \cdot \cos \theta + y'_1 \cdot \sin \theta - \rho = 0 \quad (2)$$

Where: (ρ, θ) Are the polar coordinates representing the line segment **B** in the input image.

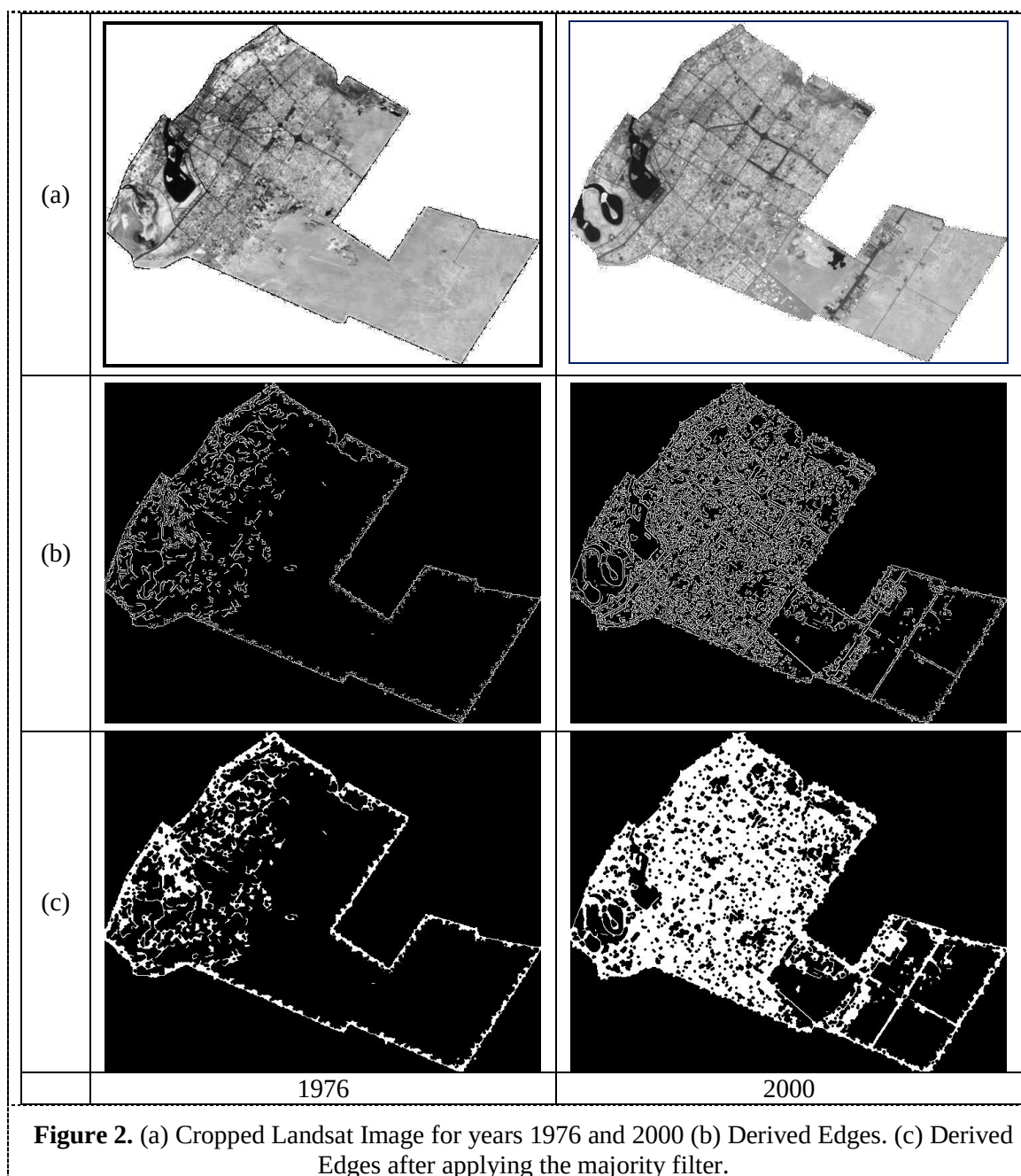
(x'_1, y'_1) Are the transformed coordinates of point 1 in the reference image after applying the registration transformation function.

Another constraint of the form in Equation 2 can be written for point 2 along the line-segment in the reference image. To automate the solution of the registration problem, a controlling framework that utilizes the primitives, similarity measure, and transformation function must be established. This framework is usually referred to as the matching strategy. In this research, the (MIHT) is used as the matching strategy. Such a methodology is attractive since it allows for simultaneous matching and parameter estimation. Moreover, it does not require complete correspondence between the primitives in the reference and input images. MIHT has been successfully implemented in several photogrammetric operations such as automatic single photo resection and relative orientation [5], [9] and [10].

6. Change Detection

After deriving the parameters of the registration transformation function, one of the images can be resampled into the reference frame associated with the other one. Within the resampled images, corresponding pixels are assumed to point at the same object space feature. Therefore, a simple pixel-by-pixel comparison/differencing between the resampled images could be used to highlight object space changes. However, radiometric differences should be expected as a result of varying atmospheric conditions and/or different sensor types. The effect of these differences can be reduced by applying intensity normalization techniques to the images in question (e.g., to ensure that they have the same intensity mean and variance values). One can argue that this

procedure would be still unreliable since it would be affected by the noise and the spectral properties associated with the input imagery [11], [12] and [13]. Instead of working with the original images, after intensity modification, one can use derived edge images as a basis for the change detection procedure. Utilizing the edge images has two advantages. First, derived edges are robust to possible radiometric differences between the registered images (e.g., due to noise and/or different spectral properties). Also, the edges would correspond to interesting features (e.g., building boundaries, roads, trails, etc.). Therefore, comparing edge images will be useful in outlining the amount of urbanization activities, which is one of the most important objectives of change detection exercises. The suggested change detection methodology starts by extracting edge cells using canny edge detector (Canny, 1986), Figure 2-b shows sample of derived edges for the study area at different years. To compensate for small geometric differences between the imagery (in the order of few pixels), a majority filter is used to fill small gaps within an area with numerous edges, as well as eliminate isolated edges, Figure 2-c.



The filtered images will highlight areas with interesting features since they would lead to a dense distribution of edge cells. Afterwards, the filtered images are subtracted to highlight areas of change. Finally, a majority filter can be applied to the difference image to eliminate small areas (since changes/no-changes are expected to be locally spread – i.e., they are not isolated), Figure 3 shows the difference image from 1987 until 2010. In the difference image, white areas indicate changes while black areas indicate parts with no change. Visual inspection for figure 3, it can be clearly noticed the areas where changed have been accrued and represented by white pixels.

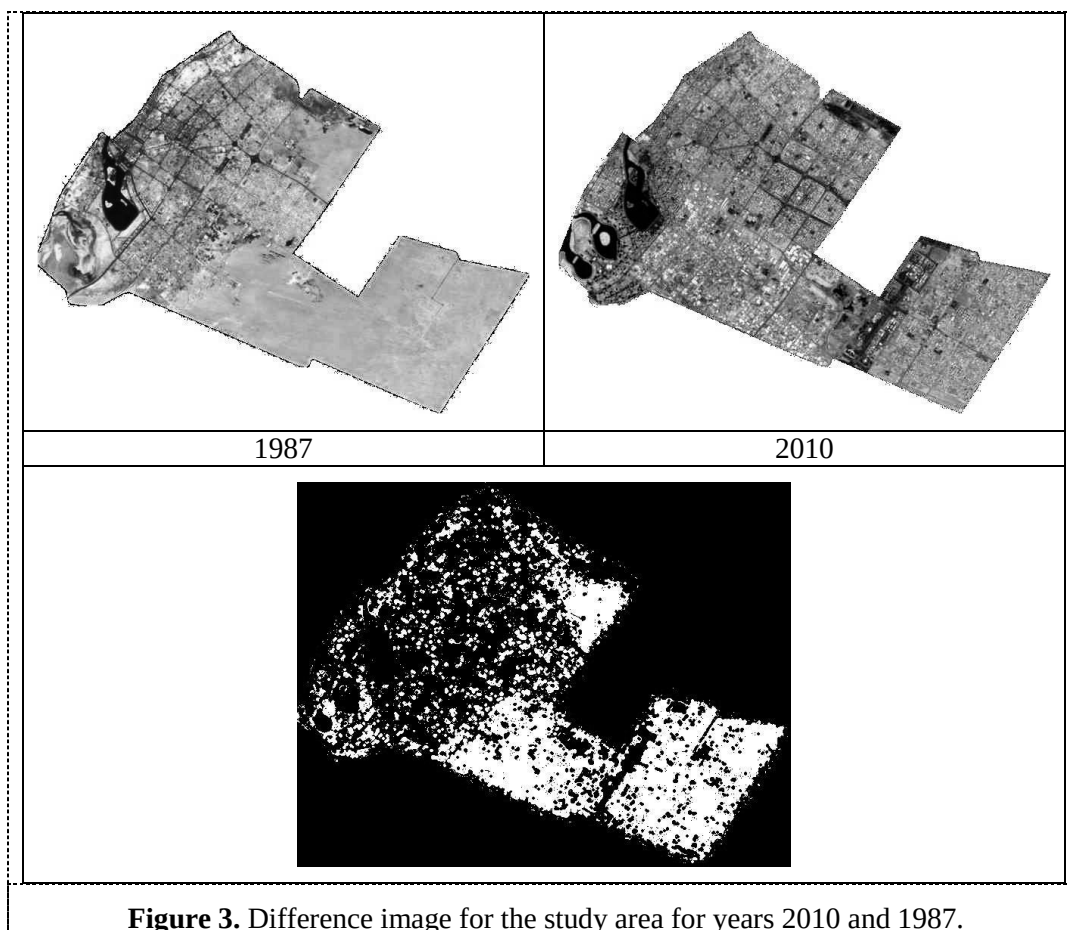


Figure 3. Difference image for the study area for years 2010 and 1987.

Figure 4 shows the clipped Landsat image for the study area for years 1976, 1987 and 2000 and the change images where white pixels represent changes. Simple statistics show that highest range of growth that represented by linear features (building and roads) have been accrued during 1976 – 1987 and stand for 36.24 % of the total urban features inside Sharjah city. Moreover, result shows that since 1976 to 2010, the cumulative urban expansion inside Sharjah city is 71.9 %.

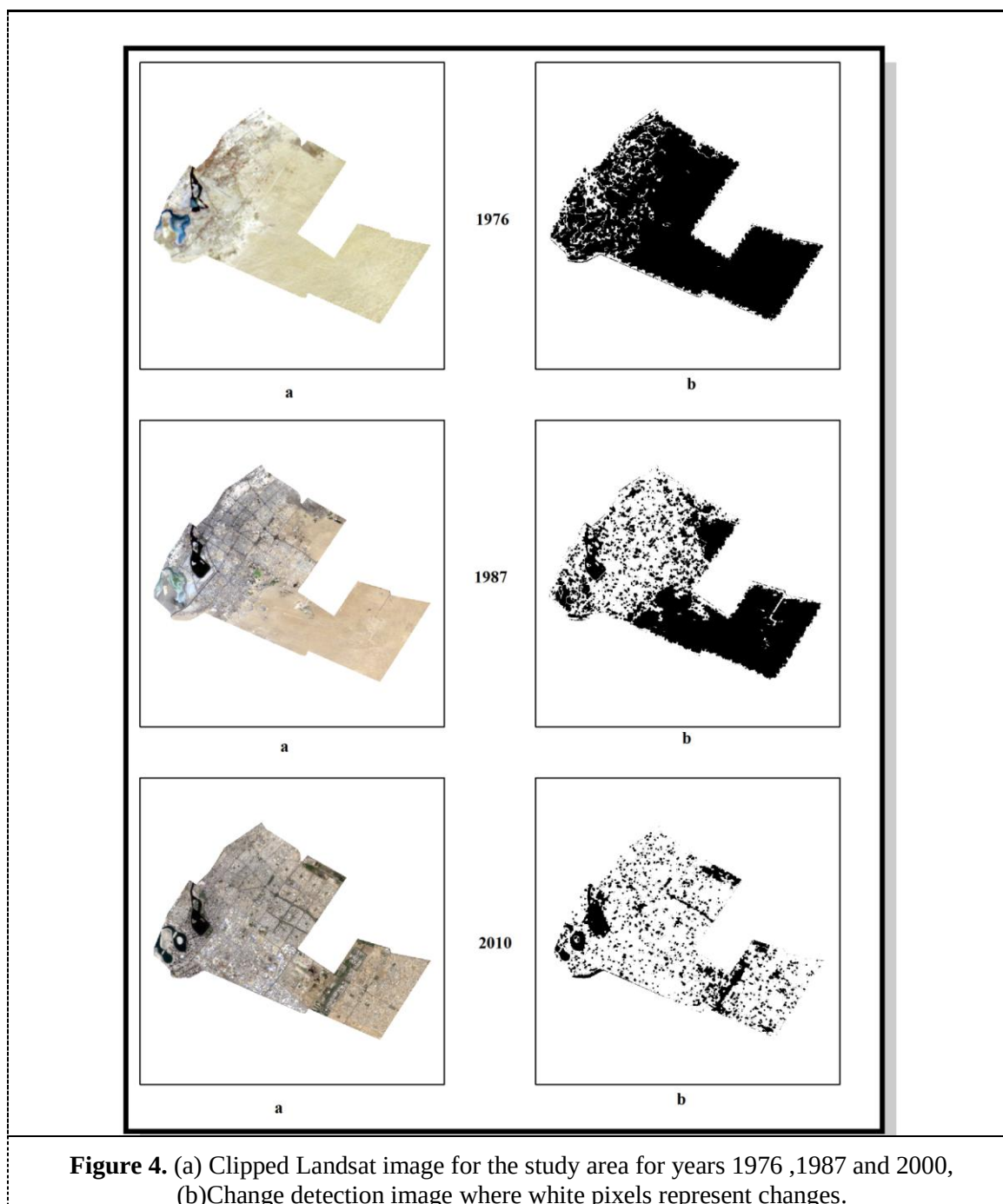
7. Conclusion and future work

This paper presents an image registration together with a suggested procedure for detecting changes between the involved images. The approach has been tested on real datasets, which showed its effectiveness in registering and detecting changes among multi-temporal and multi-resolution imagery.

The MIHT procedure has been used for automatic registration of multi-source imagery with varying geometric and radiometric properties. The presented approach used linear features (straight-line segments) as the registration primitives since they can be reliably extracted from the images. To avoid the effect of possible radiometric differences between the registered images, due to different

atmospheric conditions, noise, and/or different spectral properties, the change detection is based on derived edge images. The use of edge images is attractive since it would lead to an effective detection of urbanization activities since they would lead to a dens distribution of edge cells. Also, a majority filter has been applied to compensate for small registration errors as well as eliminating small gaps and isolated edges. The images are then subtracted to produce a change image, which could be enhanced by applying a majority filter to remove small regions. The change detection results are found to be consistent with these visually identified.

Future research will concentrate on using high resolution images for change detection at the same time establishing ground truth for quantitative evaluation of the suggested approach.



8. References

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