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SHORT COMMUNICATION

PAN-PAN Change Detection System for Satellite Imageries

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ABSTRACT

A system has been built and tested for automated change detection between multi-temporal panchromatic images. This paper discusses the implementation issues, associated tools, and finally summarises initial tests on IRS 1C/1D and other high-resolution images. Key characteristics of this system are integration of technologies having high degree of registration, normalisation of the effects of radiometry; selectivity to specific type of changes, refinement of changes by thresholding, and assignment of presence and absence of object and tools for updation/deletion of change mask. A semi-automatic technique for selection of control points in an image having affine distortion has been implemented. Linear regression is used for normalisation of the images. Two change detection techniques, namely image subtraction and image ratioing have been used to find the global change mask. Selective threshold is used to generate target mask. Target mask is shown in two colours to depict presence and absence of the object. Method based on ratioing has been found to be more sensitive to spectral variations and provides better detection of changes.

Keywords: Change detection, differencing, ratioing, threshold, registration, normalisation, change mask, registration control points, chip extraction, linear regression

1. INTRODUCTION

Change detection in remotely-sensed data is important for many applications. These include urban planning[1], strategic and tactical target detection, damage assessment[2], resource management[3] etc. Man-made objects are organised and their placement tends to be regular. For example, roads are linear, buildings are arranged in regular geometry, aeroplanes are parked parallel to one another, etc. Change detection system in defence scenario envisages detection of newly constructed buildings, roads, or airfields, and movement of aeroplanes in and out of airfields. This helps the Armed Forces to plan the movement of troops, to plan attack, and estimate the damage. Change detection in sea helps in detecting the ships and their count, thus providing an estimate of enemy's naval power.

Finding the changes between two remotely-sensed images of same geographic region is time-consuming and monotonous. Filtering out the non-significant changes is even a greater challenge. The problem is compounded due to occurrence of geometric and radiometric errors in the images because of changes in altitude of satellite, look angle of a camera, illumination levels, seasonal variations, cloud cover, and atmospheric conditions. The analyses of two digital images of the same scene taken through satellites at different locations or at different time often require registration[4,5] of images to remove geometric distortion and then normalisation for minimising the atmospheric effects.

A number of change detection algorithms like image differencing, image ratioing, and principal component analysis have been developed for optical

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panchromatic change detection[6]. Thresholding is the final step used to filter out insignificant changes for analysis.

This paper focuses on design, system components, and capability of the system.

2. METHODOLOGY

The change detection process proposed in this system has been divided into five basic steps as shown in Fig. 1. Before this, area of interest is extracted using image visualisation tool. These five basic steps are

- Registration
- Normalisation
- Change mask generation
- Filtering using threshold
- Analysis of change

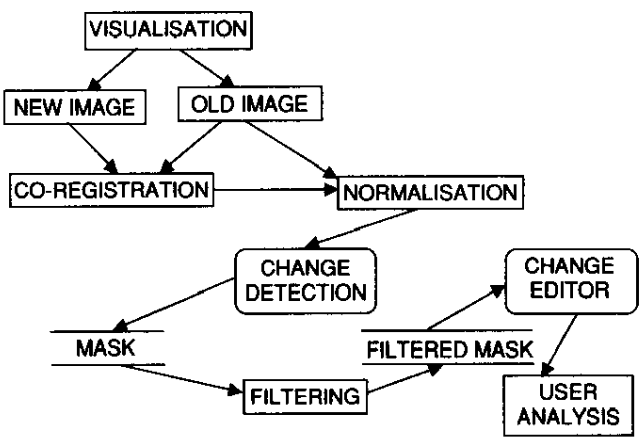

Figure 1. Steps for change detection

2.1 Registration

First step is to register two images of the same scene taken at different time. Registration accuracy depends upon the precision with which registration control points are selected. A semi-automatic technique[5] for selection of control points in an image having affine distortion has been implemented. It uses iterative segmentation and affine invariant moments for selection of control points from the extracted chip of a scene. The process of selection of registration control points is shown in Fig. 2.

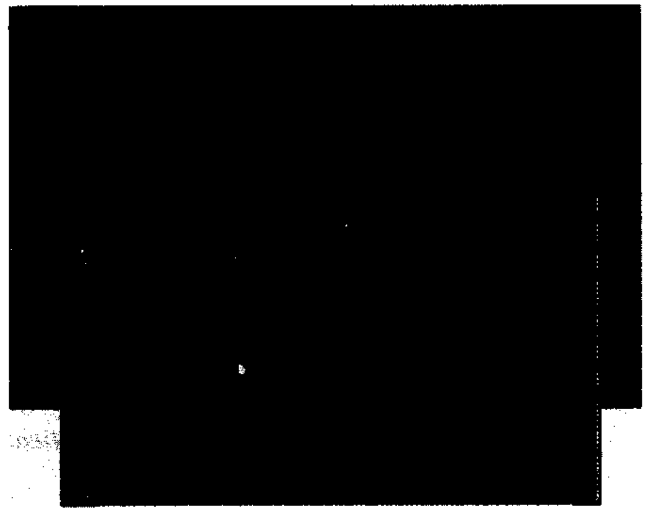

Figure 2. Extracted chip for selection of registration control points.

Facility for zoom and enhancement is also available to have minimum root mean square error, thereby achieving sub-pixel-level registration accuracy. The task is to register images with general affine distortion because these very often appear in remotely-sensed images. For example, image skew occurs due to earth's rotation. Moreover, perspective projection is usually approximated by affine function. Formally, an affine relation is described by the equations:

$$u = a_0 + a_1 x + a_2 y$$
$$v = b_0 + b_1 x + b_2 y \qquad (1)$$

where (x, y) and (u, v) are the coordinates in the old and the new images, respectively. a_0, a_1, a_2, b_0, b_1, b_2 are the transformation parameters that contain degree of rotation, shear, translation, and scaling. These are calculated using least square method[3]. These registration control points are then used to determine the affine transformation parameters. These transformation parameters are subsequently used as mapping points to register the images as shown in Fig. 3.

2.2 Normalisation

Next, a relative normalisation is performed on these co-registered images. The change in radiance values of the change area is due to atmospheric conditions, different angles of the sun, and moisture content in the terrain. To remove the spurious

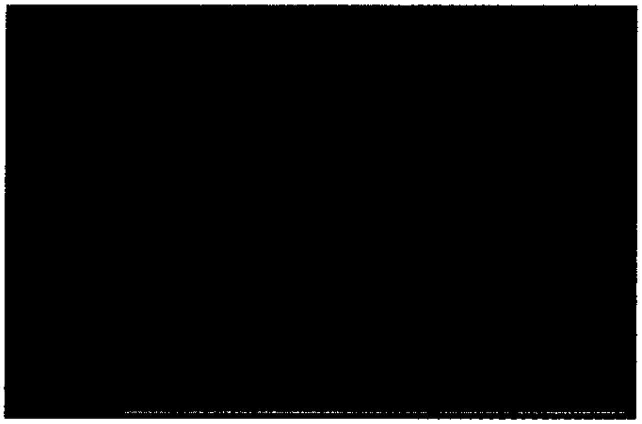

Figure 3. Registered image

radiometric differences in the image, radiometric normalisation is done using linear regression technique. The regression coefficients are calculated using both change and no-change data. Normalisation control points are chosen from those areas that have maximum correlation. However, this technique does not compensate for all atmospheric effects, particularly when clouds are present in one of the images. One must avoid these regions in selecting the control points for normalisation.

2.3 Change Mask Generation

The normalised image is then subjected to change detection process to find global change mask. Either image substraction or image ratioing technique is used for this purpose. In image substraction technique, registered images of time t_1 and time t_2 are subtracted, pixel-by-pixel, to produce an image which is also known as global change mask (M_{ij}). It can be represented as

$$M_{ij} = | imt_{1ij} - imt_{2ij} | \qquad (2)$$

In ratioing technique, the pixel-to-pixel ratio of the original and the new image is computed. Mathematically, it can now be summarised as

$$M_{ij} = \begin{cases} imt_{1ij}/imt_{2ij} & \text{if } (imt_{1ij} > imt_{2ij}) \\ imt_{2ij}/imt_{1ij} & \text{if } (imt_{1ij} < imt_{2ij}) \end{cases} \qquad (3)$$

Figure 4. Global change mask for filtering

The global change mask, M_{ij} is shown in Fig. 4.

2.4 Filtering using Threshold

Manual thresholding is done to filter out the unwanted changes from M_{ij}. Here, the *a priori* knowledge of the gray value of an object is used. Beside this, a facility is also provided to select the local gray value of the objects for setting the threshold, eg, gray value of water can be picked up for detecting the presence/absence of water in the image. The filtered mask is overlayed on the image that is displayed in the adjacent window as shown in Fig. 5.

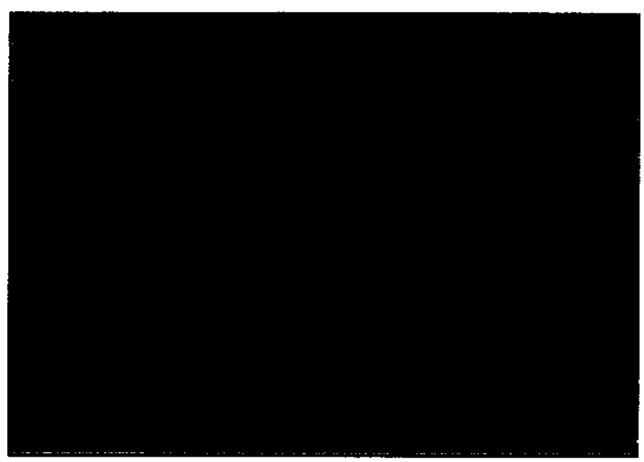

Figure 5. Filtered and overlayed mask

2.5. Analysis of Change

This mask can be viewed as solid, dashed, or dotted mask as shown in Fig. 6. Red colour mask depicts the presence and green colour mask depicts the absence of an object in the new image. Due to the presence of objects of similar reflectivity values, shadows, textures, or occlusion, some false positive or negative alarms are also seen. These false alarms can be removed using the change editor. The change editor is also used by the operator to insert previously confirmed changes. The important feature of the change editor is to assign the brushes of different sizes in two colours. This provides a real-time method for deleting all but the unimportant changes. The facility is also provided to save the analysed results in the form of gray value or coloured images.

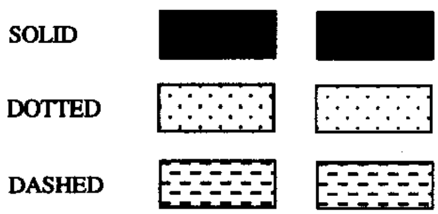

Figure 6. Solid, dotted, and dashed masks

3. EXPERIMENTAL RESULTS

Some of the sample test results are shown in Figs 7–11.

4. RESTRICTIONS & LIMITATIONS

There are certain restrictions and limitations of these algorithms. There are conditions in which the software gives false positives or false negative alarms. The limitations are:

- *Shadows*: When shadows are present within the threshold, it gives the false reflectance value and shows false positive change.
- *Occlusion*: If the object gets occluded by cloud or any other effect, that object will result as changed region.

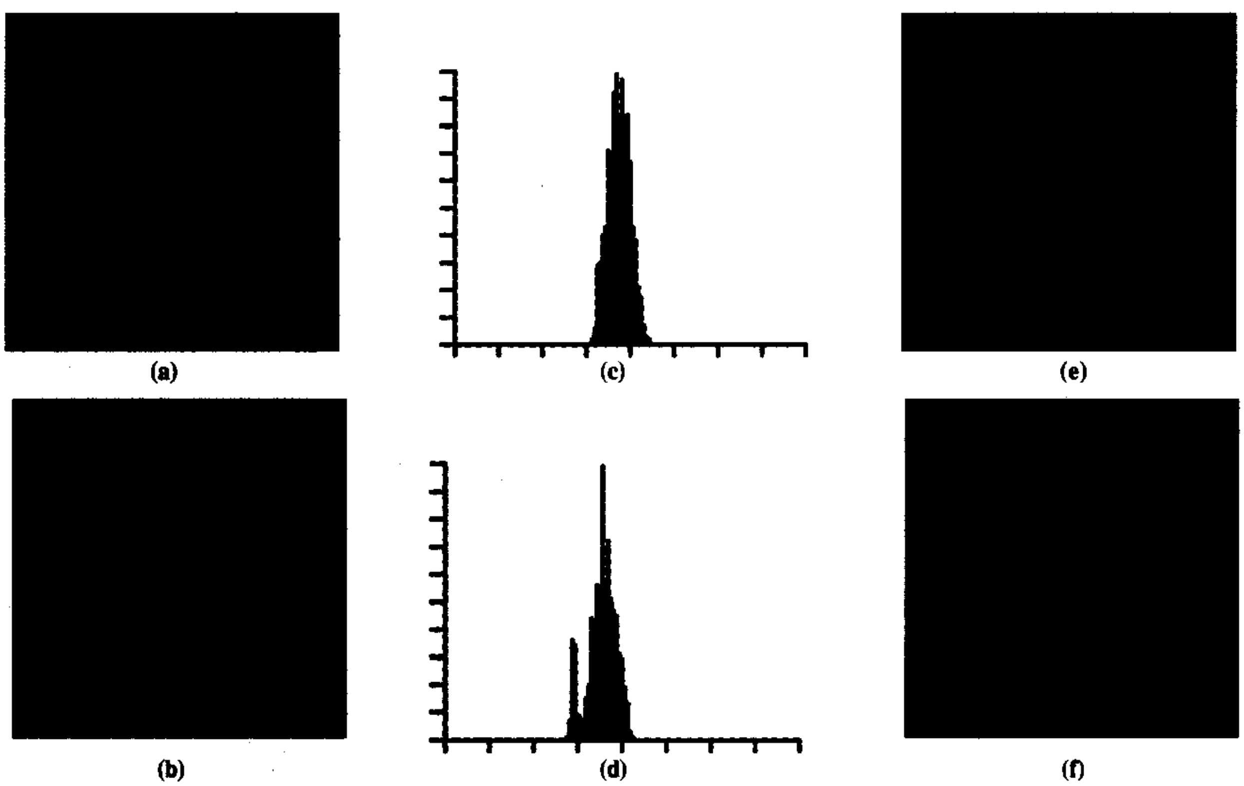

Figure 7. Dataset 1 showing dried up lake: (a) old image, (b) new image, (c) histogram of old image, (d) histogram of new image, (e) normalised image (new), and (f) overlayed changes.

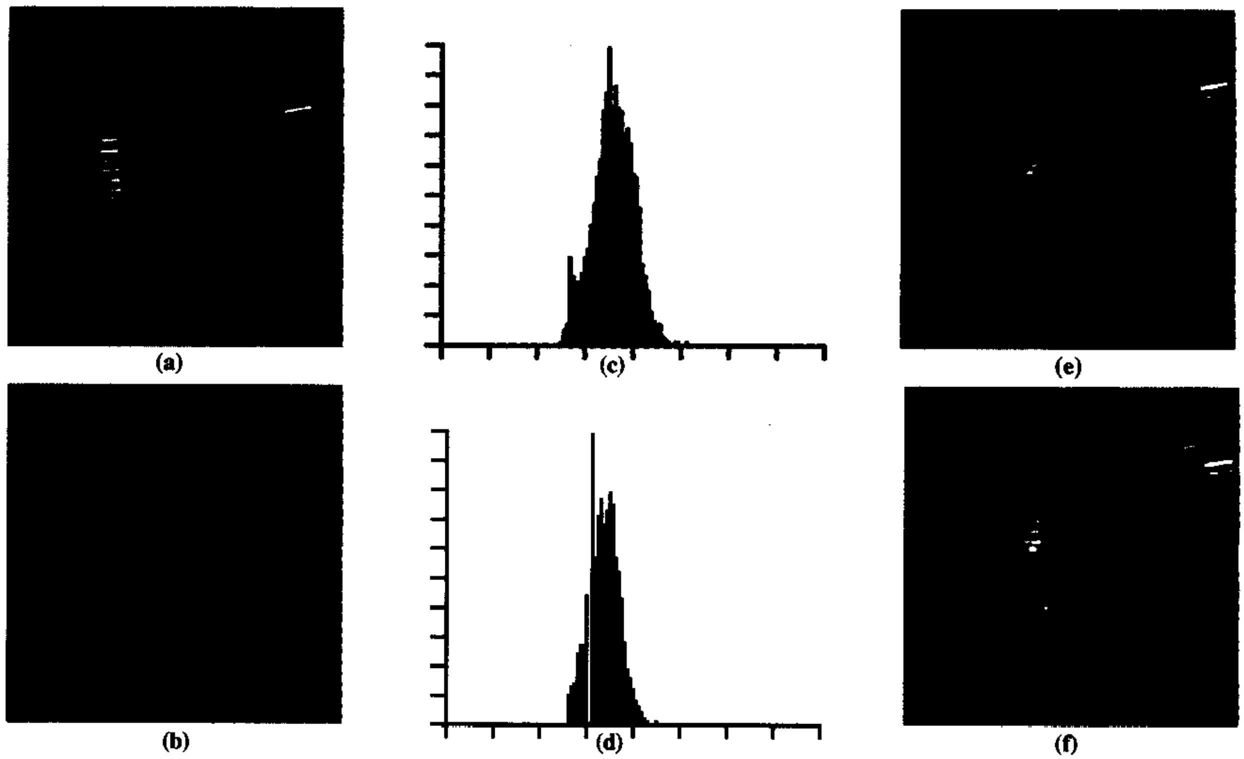

Figure 8. Dataset 2 showing newly constructed buildings: (a) old image, (b) new image, (c) histogram of old image, (d) histogram of new image, (e) normalised image (new), and (f) overlayed changes.

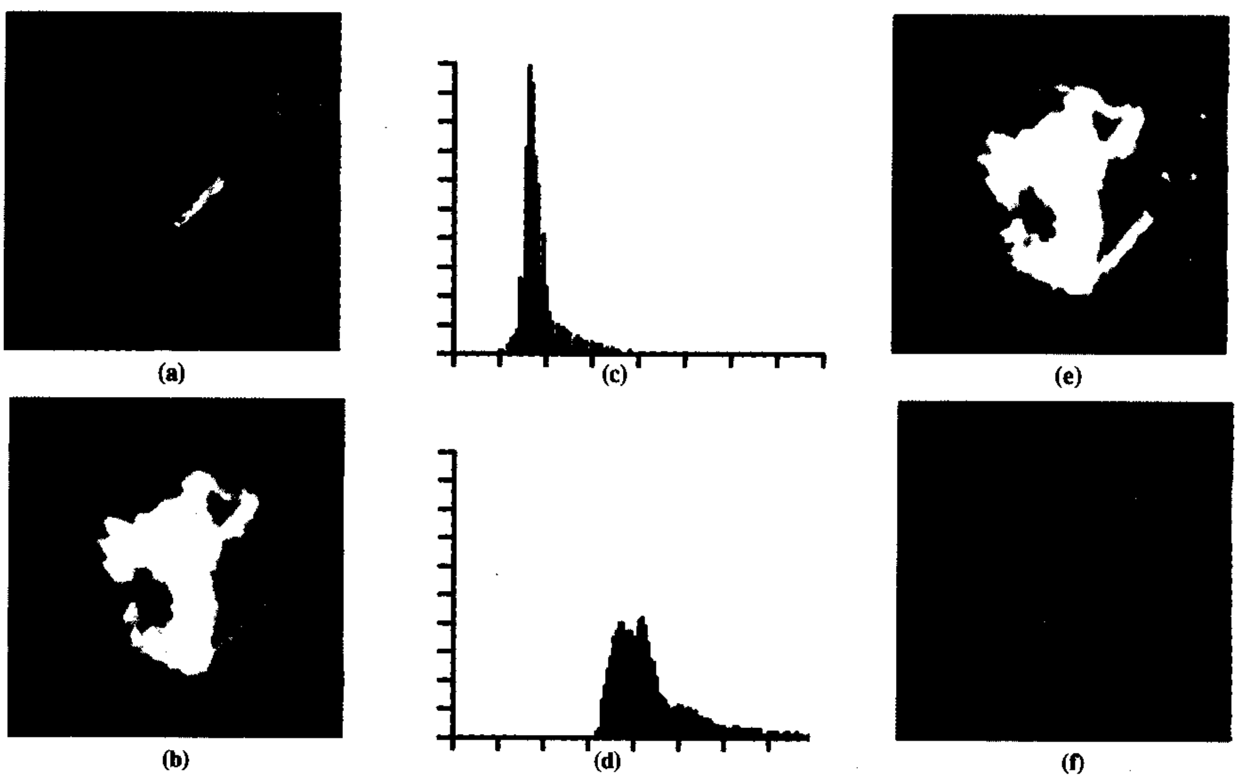

Figure 9. Dataset 3 showing clouds: (a) old image, (b) new image, (c) histogram of old image, (d) histogram of new image, (e) normalised image (new), and (f) overlayed changes.

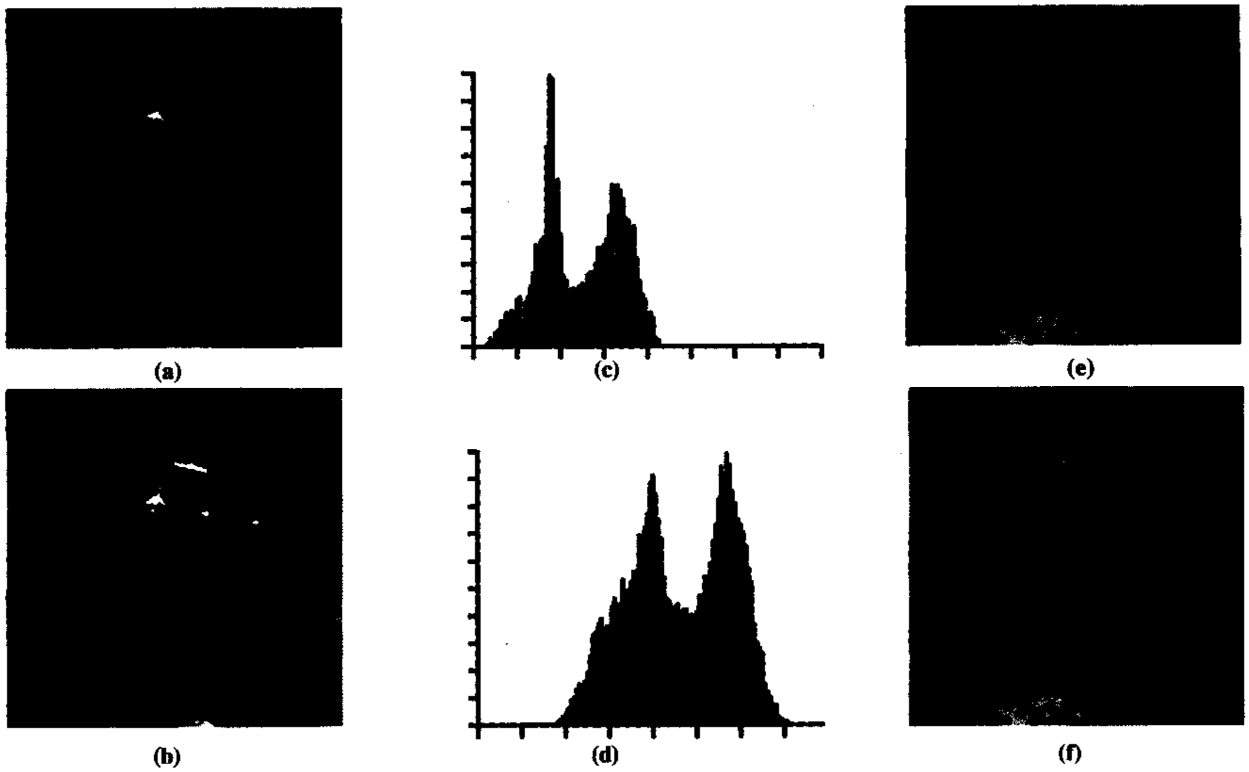

Figure 10. Dataset 4 showing presence of aeroplanes: (a) old image, (b) new image, (c) histogram of old image, (d) histogram of new image, (e) normalised image (new), and (f) overlayed changes.

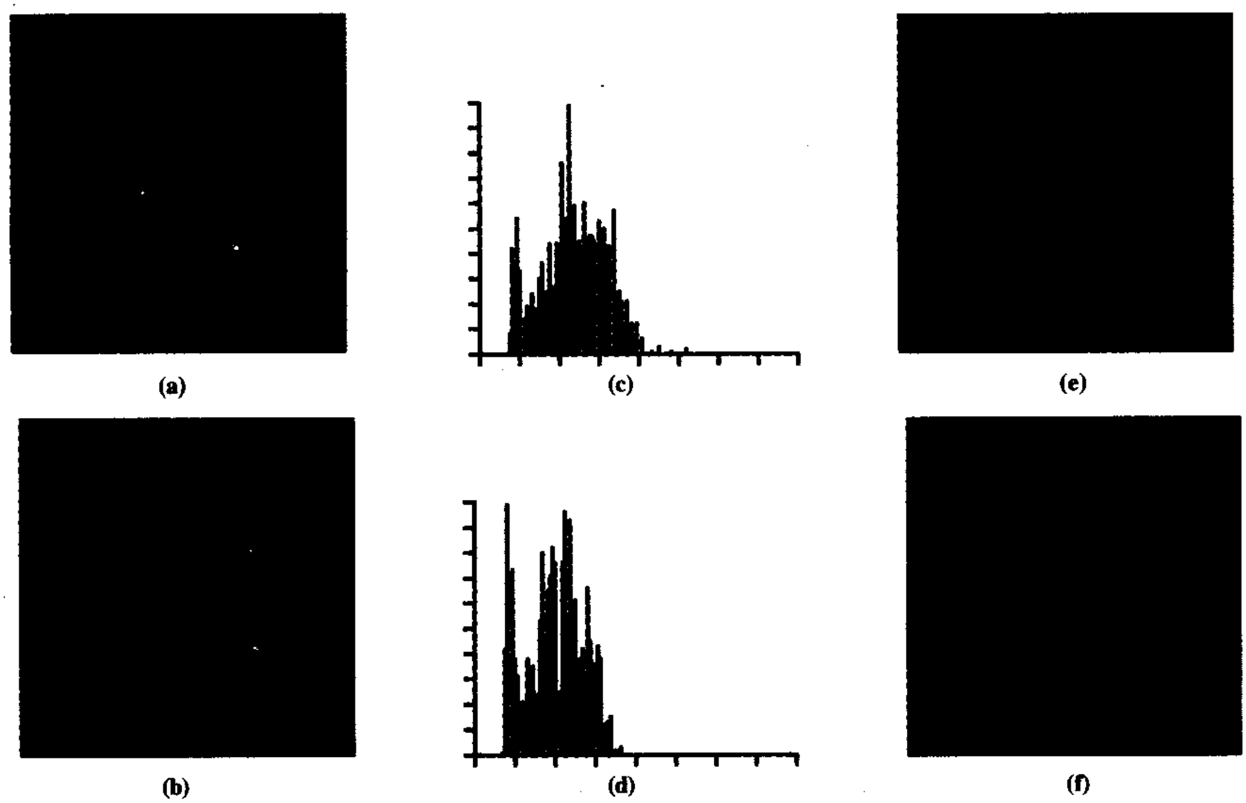

Figure 11. Dataset 5 showing presence and absence of aeroplanes: (a) old image, (b) new image, (c) histogram of old image, (d) histogram of new image, (e) normalised image (new), and (f) overlayed changes.

- *Texture*: In non-homogeneous regions low percentage threshold value will result as a change.

5. CONCLUSION & FUTURE PLANNING

An integrated change detection system has been developed to extract changes in the panchromatic images using domain knowledge of the photo-interpreter. This aids the operator to localise search for analysis in the change mask area only. The work involves integration of various technologies like registration, normalisation, change detection, thresholding, and editing tools. Precise registration and normalisation provided in this system removes geometric and radiometric distortions. After change detection, thresholding filters out the global changes based on different levels and signatures of targets. Tools are provided to remove unwanted changes and to produce a useful end-product in the form of overlayed imagery. Figure 9 shows the changes due to cloud that are categorised as unwanted changes and can be removed using change editor. This software has been widely tested on a large number of images. The results of the changes identified match closely with visually identified changes. Five dataset results are shown in Figs 7–11. Figs 7–10 show changes in water bodies, presence of newly constructed buildings, changes due to the presence of clouds, and new aeroplanes. Figure 11 shows the presence and absence of new aircraft by red colour and green colour, respectively. Presence and absence of objects can be detected using the correct threshold. The future planning is to extend this work to describe and analyse the changed region automatically.

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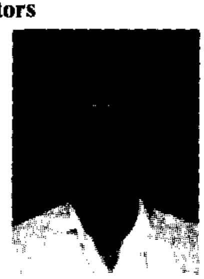
Contributors



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