Automatic Urban Change Detection from the IRS-1D PAN

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***Abstract*—The availability of increasing satellite image resolution may help city administrations in daily management of the urban development and planning. In this paper we describe a software system, called DECASAT, that automatically detects changes between two images taking from the same scene. This system has been tested successfully with panchromatic urban images provided by the IRS 1D. We also show how the result change image is integrated into the GIS of the city of Malaga (Spain).**

***Index terms*—Satellite image, urban change detection, image registration, geometric correction, GIS.**

I. Introduction

Detecting changes from a multitemporal satellite image sequence is one of the important applications of remote sensing. Since changes arise from the difference between two o more images, their precise geometric and radiometric corrections are required in order to produce reliable results.

Up to day, a variety of techniques has being applied for detecting changes in land cover, including monitoring the evolution of forested areas, burned surfaces, natural disaster, urban growth, natural resources, etc. [4][5][6][8]. Most of these applications rely on sensors, such as Landsat TM, NOAA-AVHRR, SPOT, etc., that cover a broad area with a resolution not enough for capturing details in built-up environments.

In the last few years, due to the availability of commercial higher resolution sensors (IRS 1C/1D, Ikonos, Quick Bird, etc.) a new challenging field of application has emerged in the context of urban areas. In this paper we describe a software system, called DECASAT, which automatically detects changes between two images taking from the same scene. This system has been tested successfully with panchromatic images of the city of Malaga (Spain) taken by the “1D-Pan” sensor on board of the Indian Remote Sensing (IRS) satellite.

The paper is organized as follows. Next we first outline the functioning of DECASAT. Section III and IV go into some details of the geometric and radiometric correction procedures, respectively, required for registering the two images being compared. Section V explains shortly how the change image is obtained and illustrates the result. Then, the particular GIS of the Malaga city where the change image has been integrated in is commented. Finally, some conclusions are presented.

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II. Overview of the DECASAT system

DECASAT is provided with a pair of pancromatic images of an urban area taken at different times to produce a *change image*. For further integration of the change image into a GIS the first image in the sequence need to be spatially corrected using a set of GCP (Ground Control Points) supplied by the urban department of the city of Malaga in UTM coordinates. Usually, these GCP correspond to road intersections, corner of buildings, edge of land parcels, etc. These pairs allow us to establish a typical *image-to-map* transformation as explained in parts B and C of section III. Notice that, although this stage requires the intervention of an operator in order to select those pixels in the image that correspond to the GCP, it must be accomplished only once, at the first image of the sequence.

Very briefly, given a pair of images, DECASAT works as follows:

- Both, the first (reference) image and the second image are searched for precise, reliable control points. From these points, the second image is mapped into the reference one according to an *image-to-image* polynomial transformation and a bicubic convolution [1][2].

- Since both images are taken under different atmospheric and lighting conditions, they need to be radiometrically compensated.

- Pixel values of both images are subtracted to get a difference image which is then coded into bands of colors representing the strength of the detected change.

III. Geometric correction

This process involves the transformation of the pixel coordinates of the second image to precisely overlap the reference one. This transformation is accomplished through a second order polynomial equation computed from a set of pairs of control points localised in both images. Next, we describe in more detail these processes.

A. Localization of control points

Automatic detection in the pair of images of reliable corresponding control points is essential for the system to be successful since they establish the geometry between both images. These control points should be uniformly distributed throughout the images, as precise as possible (subpixel accuracy) and in a sufficient number to allow us to handle inevitable errors in the matches.

To achieve these characteristics, DECASAT first tessellates the images in tiles (for example of 128x128 pixels) where to look for pairs of control points[1]. Currently, this is done by applying an implementation of the KLT algorithm within each of the tiles [7]. Obviously, this approach requires a coarse initial overlapping of the images, which can be easily achieved by hand.

Although KLT was originally proposed for detecting and tracking image features in stereo images it has demonstrated to perform well in our case because of the small disparity of the images. Figure 1 shows an example of the tessellation and control point pairs detected.

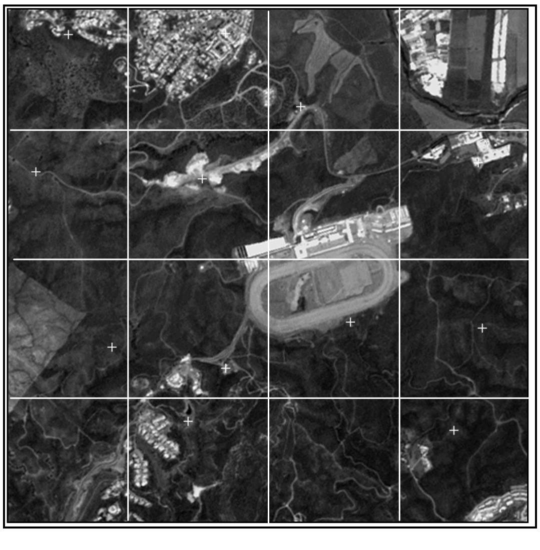

Figure 1. Tessellation of an image and control points detected by the KLT algorithm (marked as +).

It must be pointed out that Malaga is at the coast and therefore a considerable portion of the image corresponds to the sea, where control points detected by the KLT algorithm are (as expected) very unreliable. To overcome this problem DECASAT limits the search of control points to a polygonal region of interest defined by hand.

B. Coordinate transformation

From these pairs of control points we can compute a polynomial equation that transforms pixel coordinates from one image to the other. In particular, we have used the expressions:

$$x' = a_0 + a_1 x + a_2 y + a_3 xy$$
$$y' = b_0 + b_1 x + b_2 y + b_3 xy$$

where (x',y') and (x,y) are the corrected and uncorrected pixel coordinates, respectively. This model can manage scale, shift, rotation, shear and inversion.

The 8 coefficients of the above equations are determined through an iterative least-square fit that discards those control points that contribute the most to the root mean square error of the residuals. Typically, starting with almost 1100 pairs of control points[2], and limiting the error to a maximum of 1 pixel, the system ends up with around 500 pairs.

C. Gray level transformation

Now, the gray levels at pixels in the corrected image are obtained based on the values of the uncorrected one through a cubic convolution encompassing 16 neighbors.

This resampling procedure is more time consuming than others (nearest-neighbour or bilinear interpolation) but guarantees much better estimates [1], [2].

IV. Radiometric correction

Ideally, a given entity captured in two different satellite images (with the same sensor) should appear with the same pixel values. In practice, this is not so due to inevitable different lighting and atmospheric conditions. Thus, a radiometric correction is required. Two alternative were studied: absolute radiometric correction using an analytical model and a histogram-based gray level modification.

The first one showed to be not practicable at all because it requires a sophisticated model that accounts for a number of parameters (some of them unknown) like satellite orbit, local atmospheric conditions, seasonal and geographic variations, clouds, rain, etc. Consequently we have implemented the second one, which modifies the pixel values in one image to obtain a new corrected image with a histogram similar to the one of the reference image [3]. Notice that similar histograms means that the images achieve similar brightness, contrast and distribution of gray levels. This technique performs better the greater the

[1] Typical IRS panchromatic image size for the Malaga metropolitan area is 5120x5120 pixels which, for tiles of 128x128 pixels, gives 40x40 tiles.

[2] One for each tile except coastal zone and tiles where the KLT algorithm doesn't find correspondences.

number of pixels. For the images we are dealing with (5120x5120 pixels) the results are considerable good (see figure 3).

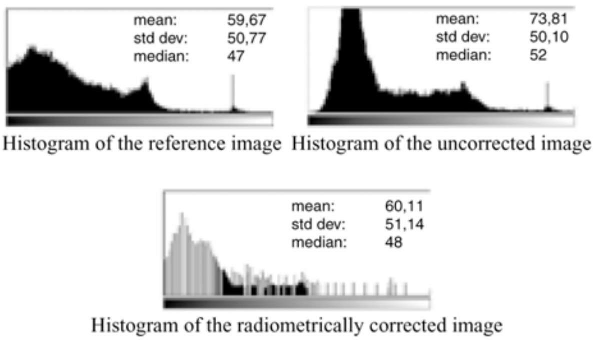

Figure 3.- Histograms of the three images involved in a histogram specification procedure.

V. OBTANING THE CHANGE IMAGE

Once the images are geometric and radiometrically corrected they are subtracted (in absolute value) to get a difference image. From it the change image is obtained by first filtering out isolated pixels and small areas and then coding the remaining pixels into bands of colors representing the strength of change (see figure 4).

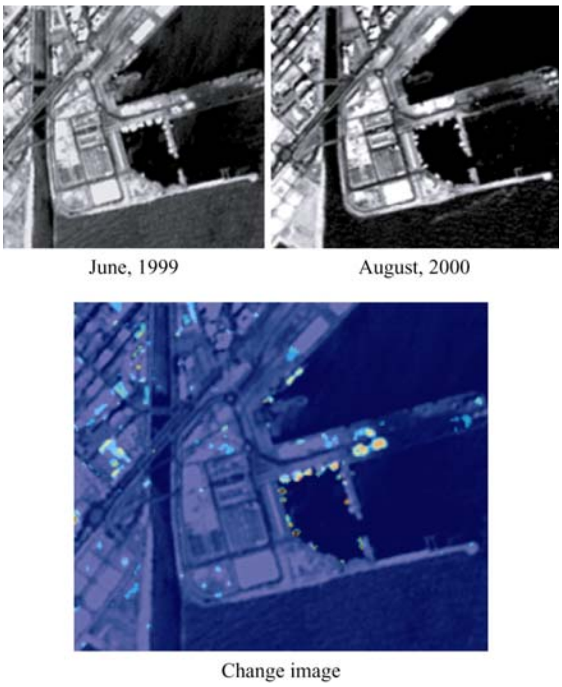

Figure 4. Up: portions of the two images being compared. They show part of the harbour of Malaga. Down: change image superimposed to the reference image (June, 1999). Since this image has been converted to gray scale we can notice the color used to code the strength of change (changes appear brighter).

VI. INTEGRATING THE CHANGE IMAGE INTO A GIS

In addition to provide regular, inexpensive monitoring of the evolution of the city over time, change images become much more useful when integrated into a geographic information system (GIS).

In our case the GIS, developed at CEMI (Computing Center of the City of Malaga), combines aerial and satellite images with a digital cartography and alphanumeric databases stored in a legacy mainframe. Such a system, developed under the already existing Bentley's Microstation environment. provides the urban technical staff with a powerful application to access a complex set of data through a simple and easy to use interface. Notice that, the integration of the change image produced by DECASAT into the GIS is possible because it comes spatially corrected, which means that changes match their corresponding items in the digital cartography.

The size of the city of Malaga and surrounding areas is 5120x5120 pixels, which covers and extension of 30x30 km., approximately. This size makes difficult over terrain inspection work carried out by urban department inspectors. Automatic change detection permits inspectors to focus on concrete areas to check for. The following examples illustrate some of the possibilities of the complete system.

Figure 5 shows the application GUI for supervision of the rehabilitation process of the historical center of Malaga sponsored by European Union. Left panel shows the spatially corrected aerial image. Right panel shows digital cartography superimposed to the change image. Brighter regions (changes) in the figure indicate rehabilitation works.

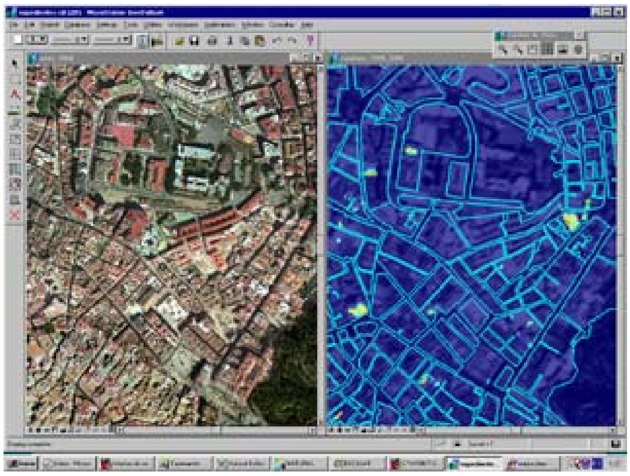

Figure 5.- Historical center of Malaga.

Left panel in figure 6, with the digital cartography and satellite image superimposed, enhances the precision achieved in the spatial correction. Right panel shows the change image. If an operator zooms a region of change, the aerial image will be shown in the left panel providing an approximation to the region, as observed in figure 7. It displays a zoomed aerial image along with the cartography . The bigger change detected in the change image (right panel) corresponds to improvement works of the parking of a soccer field. Other minor changes were also verified by inspectors as real changes corresponding to terrain movements and building constructions.

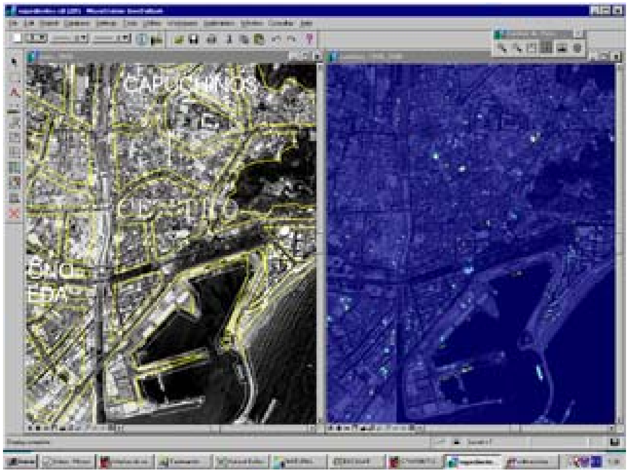

Figure 6.- Satellite and change images of Malaga harbour area.

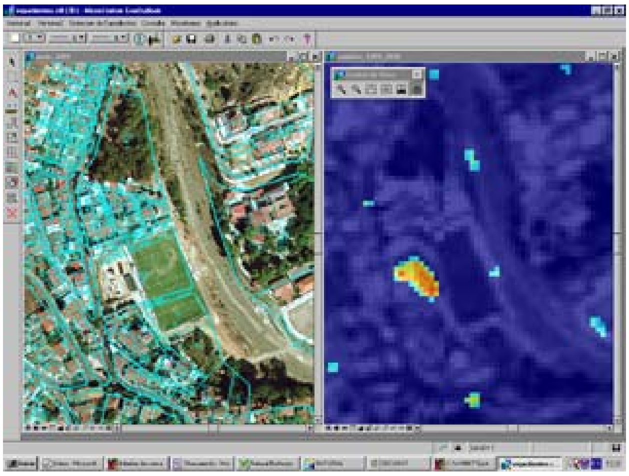

Figure 7.- Improvement works of a Malaga soccer field parking

VII. CONCLUSIONS AND FUTURE WORK

Currently, commercial satellite images provides us with a quick and inexpensive source of information that can assist urban technicians in monitoring new constructions and urban landscape modifications. Usually, these tasks are made visually from aerial photographs, which take large amounts of time (meaning large amounts of money), become tiring for the person and are susceptible to errors of omission. Since the data recorded by imaging systems on-board satellites is digital, an automated way to detect change may significantly reduce the current cost and manpower for interpretation.

In this paper we have described a system, named DECASAT, that detects urban changes fairly accurately. DECASAT has been applied to a temporal sequence of images of the city of Malaga (Spain) provided by de 1D-Pan sensor, on board of the Indian Remote Sensing (IRS) satellite.

The integration of the change image into a GIS has improved not only the detection of suspicious actions but also it has facilitated the retrieving of related information to check for permission of construction, debts, historical data of properties, etc. In addition, retrieving economic and environmental data from other local departments is as easier as clicking at the appropriate symbol on the same interface.

Currently we are working on improving some aspects related to the integration of change image into the GIS. For the next future, we plan to apply image processing techniques in combination with information from the GIS data base to classify and interpret changes.

Acknowledgment

We wish to thank the “Centro Municipal de Informatica (CEMI)” of the local administration of Malaga for its collaboration and help.

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