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CHANGE DETECTION ANALYSIS IN MULTITEMPORAL SATELLITE IMAGE SERIES

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Abstract

The present work aims to perform ratio and difference techniques to detect changes in Nova Friburgo, Rio de Janeiro – Brazil caused by landslides. Using Landsat-5 images obtained before and after the landslides in January 2011 that was possible. These techniques allow identifying abrupt change on spectral response in remotely sensed images. There are many factors influencing the success of applying change detection techniques, among them, one could mention: atmospheric condition, sensors calibration procedures, water content in soil, differences in sun angle at the image obtaining. Neighborhoods and forested areas were destroyed causing major problems to citizens and slopes subject to new landslides. Given a set of spectral bands, it is difficult to define a good threshold for histogram and the best bands in order to use change detection analysis. The better result was obtained by using the band TM7 and TM5 (infrared) with difference between images technique. Kappa was set in 0,9255 and 0,9243, respectively to detect changed areas in land-scape. Noise in result was frequently and its minimization was essential. To image ratio technique was obtained good results (TM3 with 0,8582 Kappa) but with great difficulties to define a good threshold cut-off in image histogram.

Keywords: Change Detection, feature selection, remote sensing, landslides.

1. Introduction

The methods to perform an automatic change detection analysis from Remote Sensing products are based, in general, on the difference of spectral behavior of the targets corresponds to a difference in Earth coverage. Considering two images co-registered from the same area, they could be different because of some factors, such as: (i) atmospheric conditions, (ii) procedures to calibrate sensors (iii) moisture in soil (iv) and vegetation coverage (Carrilho *et al.*, 1996).

The change detection methods are largely used. Specifically, it is possible to use image algebra based on division and/or subtraction from bands that were obtained on different time. This calculation is intensely employed to detect deforestation, changes in soil use, and other purposes (Weismiller *et al.*, 1977; Gong *et al.*, 1992, and Manavalan *et al*., 1995).

In recent years, different methods were proposed for change detection, which takes into account distinct complexity, refinement and robustness. The change detection is very useful for different applications, for instance culture rotations, seasonal changes in pastures, damage evaluation, disasters monitoring and other environmental changes.

The Remote Sensing detects changes in surface coverage by the change in radiance values, but must take into account other factors that modify radiance values (Ingram *et al*. 1981, apud Singh, 1989). These other factors are: differences in atmospheric conditions, sun – object – sensor geometry, soil moisture, and so on (Jenson, 1983). These factors may impact the results reducing partially the appropriate data selection.

The objective of this work is to perform a change detection analysis based on difference and ratio between images, obtained in different times, occurred a dramatic landscape in Rio de Janeiro – Brazil, in the city of Nova Friburgo whose area is urbanized.

Automatic change detection allows identifying changes in Earth surface related to natural disasters, through satellite images. These images can be obtained before or after some event such as landslides, which generally results in fatal victims, material losses and damage to the environment.

This procedure allows evaluating spatial dynamic such as urbanization, natural disasters and other changes occurred because of the landscape. The basic premise is that all changes in Earth surface will result in changes of radiance values (Singh, 1989). Then, if the satellite images are used, the changes can be interpreted by different values from digital counts on images.

2. Study Area

Based on visible range imaging from sensor TM – Thematic Mapper of Landsat-5 satellite, the study area covers about 571 km². Most of this this area are located in Nova Friburgo. In north portion, are located Sumidouro, Duas Barras e Bom Jardim municipalities. This region has a very dramatic landscape. The area that suffered most landslides is located at the urbanized area in Nova Friburgo. Figure 1 shows a map with the study area location.

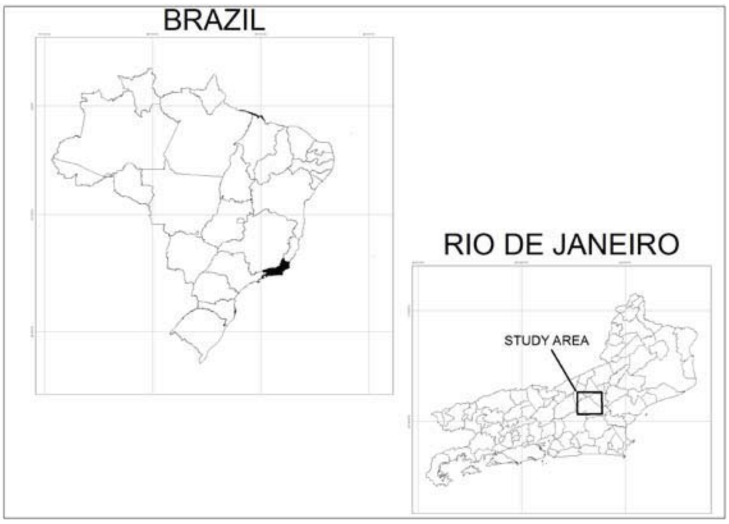

Figure 1: Study Area localization.

3. Materials and Methods

The Landsat image data was obtained with DGI – Divisão de Geração de Imagens from INPE – (Institute of Spatial Search) avaible in http://www.dgi.inpe.br/ related the date: 26.08.2010 and 13.08.2011.

The images were correctly preprocessed, allowing the trial and error method with all bands and thresholds. The band 6 from satellite was not used because correspond to infrared thermal.

It was essential to minimize the atmospheric effects through radiometric corrections, as well correct the image geometry distortions by geometric correction in Landsat-5 images. With radiometric normalization (relative calibration) the histogram from image t_1 was used as parameter to adequate the image t_2. The result was a new image t_2 radiometrically normalized and ready to geometrical correction. To perform the geometrical correction on the images, it was used the software ERDAS Imagine 9.2, running the module Image Geometric Correction, whose correction model selected was the Polynomial (first order) geometrical transformation model with rational functions, to rectify the orbital images.

The indication of data from Earth project system was the Universal Transverse of Mercator (*UTM*), with horizontal *datum* WGS84, fuse 23 e *K* zone. The essential use of change detection techniques is when the images need to be consistently registered to avoid the appearance of edges and registry errors which was considered as changes.

This work has used simple algebraic operation, based in subtraction and division from t_1 by other image t_2, which cover the same area. The subtraction technique between images was applied in all bands (except on TM band 6) in order to defining thresholds, observing the trial and error method. The method was applied to the corresponding band in two temporal cut.

To use ratio between bands, was used the Equation (1), where $X^k ij(t_2)$ is the pixel value to k band to the pixel x in line i and column j in time t^2. $X^k ij(t_1)$ is the pixel value to k band to the pixel x in line i and column j in time t_1. If the intensity of reflected energy is near in both images, so $R^k ij = 1$, that means no difference in pixels. C is the constant that allows the technique because zero pixel value can't process the technique.

$$Rx^k ij = X^k ij(t_2) / [X^k ij(t_1) + C] \quad (1)$$

To difference technique, we use the formula (2) where, $X^k ij$ is the pixel value to *k* band to the pixel in line *i* and column *j* in time t_1 and t_2. C is the constant that allows the technique to give positive values in result determined in $R^k ij$.

$$Dx^k ij = X^k ij(t_2) - [X^k ij(t_1) + C] \quad (2)$$

The threshold value is used to select changed areas by histogram cut. According to Deer (1995) there are two main methods for defining the threshold, which are: a) interactively, when the analyst will set the threshold until has found the expected result, b) statistically, for example, using standard deviation. The method *a* the analyst could identify a number of instances of desired change occurring and in *b* the proposition is the computer determinate the characteristics of the change by statistical analysis or learning algorithm. The method a was used in this work.

In order to perform a change detection analysis, the flowchart below shows the steps. Basically, images t_1 and t_2 allows comparisons. The techniques were used in next step, creating a change detection map, aim of this work.

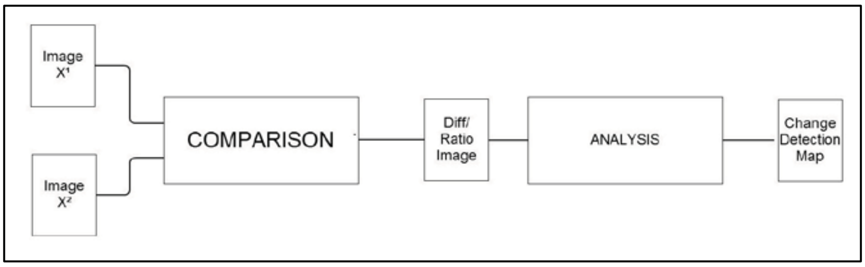

Figure 2: General model to change detection based on binary changes. Adapted from Bovolo and Bruzzone (2007).

It was analyzed the characteristic of landslides on the image after the landslides, enabling the identification and interpretation of visual scars in the landscape.

The histogram matching was very useful for matching time series data of the scenes. To generate a good result, it was necessary to observe the following: a) the general shape of the histogram curves should be similar; b) relative light and dark features in the image should be the same; c) change detection, the spatial resolution of the image should be the same date and d) the relative distributions of land covers should be about the same. If one image has clouds and the other does not have, then the clouds should be removed before matching the histograms.

For the geometric correction, the chosen method was the polynomial rectification, which is a process of projecting the data onto a plane and making it conform to a map projection system. Since the two images were recorded, projection system was associated with map coordinates, reducing the noise and the formation of edges in the detection of changes.

To verify the accuracy of change detection product (ratio and difference applied in TM bands) was used Kappa Index Agreement to have a quantitative analysis. Gong and Howard (1990), suggest Kappa index to verify thematic classifications. Was generated a reference image, locating landslides areas and classifying them. A comparison between classified areas in reference image and result classified change detected areas was done and the result analyzed.

4. Discussions and Conclusion

In parallel with the threshold set, the choice of the better band was very important. It was noticed that the farther the visible spectrum (0.4 to 0.7 цm) have had better answers to difference technique. This is closely related to the spectral signature of targets, when the bands TM5 and TM7 of the sensor of the Landsat, which correspond to the mid-infrared in the electromagnetic spectrum.

As table 1 show, the best result was in Band TM7 with difference technique. Band TM5 and TM7 in difference technique result, was very near, showing that this two sensor bands, represents the best bands to difference technique. In Figure 3, was possible see change detection areas identified by difference in band TM7.

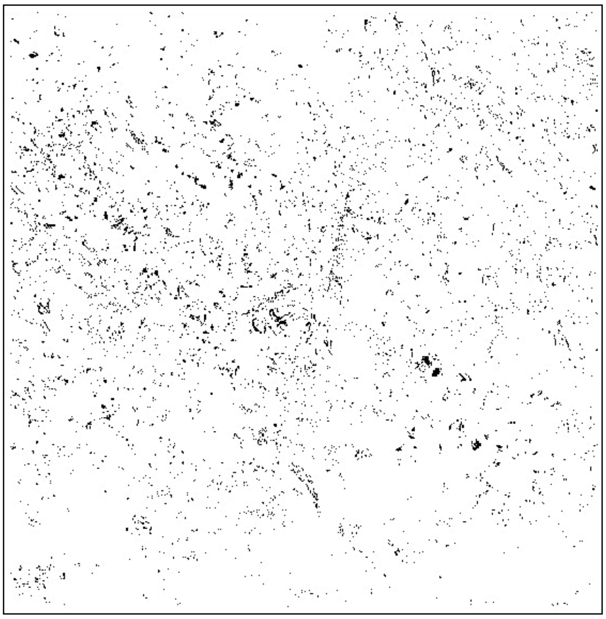

Figure 3: Difference TM7 change detection result.

To ratio technique, the best results was in band TM2 and TM3, showing that TM3 – red in visible, represents good contrast between forested areas and deforested areas (urbanized, exposed soil, etc.). The threshold set was very hard to ratio technique because the non-change results in pixel value are grouped “near” zero and the transition was not easily identifiable.

Table 1: Result by quantitative Kappa Index Agreement analysis in processed images.

	Difference	Ratio
Band 1	0,7906	0,6644
Band 2	0,6955	0,8575
Band 3	0,8888	0,8582
Band 4	0,4601	0,2511
Band 5	0,9243	0,6374
Band 7	0,9255	0,7567

It is noteworthy that the detection of changes in land cover, must also take into account differences in illumination, atmospheric conditions, sensor calibration, soil moisture and finally differences in recording the two images. Regardless of this type of "noise" in search results, the analyst never knows what actually changed and what changes should not be considered. There are many techniques for detecting changes in Remote Sensing that are being used in accordance with the proposed objective. With a large knowledge of techniques, the work can be more fast and targeted to the main objective.

Finally, it is important to stress that to achieve a satisfactory program of monitoring natural disasters; change detection is presented as an possible tool. For the detection of abrupt changes, the techniques chosen in this study had satisfactory results. We can’t define one technique that detects changes in all cases; the experts should have a complete range of techniques available for monitoring and prevention of natural disasters.

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6. References

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