Change detection methods for multi-temporal analysis of satellite data aimed at environmental risk monitoring

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Key words: remote sensing, change detection

SUMMARY

In the last years the topic of Environmental monitoring has raised a particular importance, also according to minor short-term stability and predictability of climatic events. Facing this situation, often in terms of emergency, involves high and unpredictable costs for public Agencies.
Prevention of damages caused by natural disasters does not regards only weather forecasts, but implies the constant attention and practice of monitoring and control of human activity on territory. Practically, the problem is not knowing if and when an event will affect a determined area, but recognizing the possible damages if this event happened, by adopting the adequate measures to reduce them to a minimum, and requiring the necessary tools for a timely intervention. On the other hand, the surveying technologies should be the most possible accurate and updatable in order to guarantee high standards, involving the analysis of a great amount of data. The management of such data requires the integration and calculation systems with specialized software and fast and reliable connection and communication networks.
Change detection analysis serve to facilitate individuation of environmental temporal variations, contributing to reduce the users intervention by means of the processes automation and improving in a progressive way the qualitative and quantitative accuracy of results.
The research investigate automatic methods on land cover transformations by means of "Change detection" techniques executable on satellite data that are heterogeneous for spatial and spectral resolution with homogenization and registration in an unique digital information environment.
In the present work we tested some areas of study particularly interesting for the knowledge of the morphology changes of land cover, in particular the area of the coast of Manfredonia characterized by the presence of important industrial sites and protected area of the Park of Alta Murgia with frequent episodes of land transformation.
We tested the usability of heterogeneous and freely available images to realize a Change detection process to achieve fast and low cost system of analysis.
We used archival images Ikonos and WorldView II comparing with orthophotos and with Google Earth images (Geo Eye) making pre-processing of resampling, coregistration, histograms normalization.
The pre-processing has allowed to apply the change detection algorithms with good results, in these tests we have obtained very encouraging results compared to those obtained using satellite images with all the available spectral bands such as the recent Worldview II that we used as control data-set.

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1. INTRODUCTION

The monitoring techniques of dynamics of evolution of natural phenomena and the interactions that these have with the anthropic manufactured, are an important factor of aid for the processes of decision / intervention in a great variety of applications.
The detection of the change of the land cover, through automatic analysis of satellite images taken on a same area in different times, has become one field of research development in continuous improvement.
The methodologies for the analyses of the changes techniques are defined of "Change Detection" and they consist in that trials to identify and to quantify the temporal differences of state of objects e/o phenomena in one determined area of the terrestrial surface.
In general the methods of Change Detection compare images acquired by the same sensor to assure the comparability of the various aspects.
In many cases we are forced to use multi-temporal images coming from different sensors. For example, in analysis of wide historical series, some data could have been acquired from sensory more existing or that currently have stopped acquiring images for technical reasons or images without documentation or metadata, or images with cloudy coverages.
The automatic procedures of Change Detection doesn't replace the experience of the human operator but the speed and the rapid repeatability of the elaborations with opportune algorithms it allows an effective use in a lot of situations.
At the same time the availability of information out of visible electromagnetic range allows consistent advantages in comparison to the human eye.
It will be necessary, therefore, for every type of job to appraise the costs and the benefits offered by the automatic procedures instead that from the ability of experienced operators.

2. THE AREAS OF TESTS

The study areas are portion of AltaMurgia Regional Park in Apulia region, located inside the town confinements of the city of Andria. Such portion, situated in the proximities of Castel del Monte, represents therefore an area of notable naturalistic and landscape interest, as well as of promotion and retraining of agricultural and pastoral activity.
With the purpose to guarantee the necessary guardianship of a very interesting area, it is fundamental to quickly equip it with control methods and effective monitoring to individualize the zones where environmental tie is broken with building abusiveness or unauthorized cave and dump. To reach this purpose, the methodologies of Change Detection can result extremely effective and worthy of consideration.
The data used in these tests are:
Image by the sensor IKONOS-2 with coordinates of the vertexes: Lat: 40.93°-Long: 16.19° and Lat: 41.06°-Long.: 16.33°, in the UTM-WGS84 Datum with 1 mt. spatial resolution in the panchromatic acquired 18-05-2000, at 09:33. IMG 1 (Alta Murgia)
The ortophotos of the Territorial Informative System (www.sit.puglia.it) predisposed by the

Apulia Region, acquired in December 2008, IMG2. (Alta Murgia)
The images of Google Earth, with acquisition with GeoEye sensor, it is datable to the September 2010 and such image will be denominated IMG3. (Alta Murgia)
Image by the sensor IKONOS-2 with coordinates of the vertexes:
Lat: 41.56°-Long: 15.82° and Lat: 41.69°-Long.: 15.98° in UTM-WGS84 Datum with 1 mt. spatial resolution in the panchromatic acquired 19-06-2004, at 09:48. IMG 4 (Manfredonia)
Image demo of the sensor WoldView II of a portion of the same area acquired the 04-02-2011, at 09.29 with resolution of m. 0.50. IMG 5. (Manfredonia)
The focus of this study is the verification of the obtainable results under non conventional conditions with materials and data already free available even if of very heterogeneous typology.

3. PRE-ELABORATIONS

3.1 Pansharpening

The algorithms of pan-sharpen allow to exploit the most elevated spatial resolution offered by the panchromatic band of the data getting a natural color image.
To realize our comparisons we have decided, contrarily to the normal procedure, to reduce the four bands of all the available images to the RGB natural colors.
We performs the operation of pan-sharpening on the Ikonos IMG1(Alta Murgia) to make it how much more homogeneous to the IMG2 and IMG3 in RGB and the Ikonos IMG4 (Manfredonia) with Worldview II IMG5 in RGB too. We will get all images in RGB natural color with 1mt resolution.
The softwares offer special tools for pan-sharpening with specific algorithms:
" HPF Resolution Merge; " Modified IHS Resolution Merge; " Subtractive Resolution Merge; " Ehlers Fusion Resolution Merge; " Etc…
We have used the algorithm "Subtractive Resolution Merge" that offers the correct compromise between the elevated spatial detail and a realistic representation of the colours.

3.2 Co-registration

The correct and perfect overlap of the images is a fundamental requisite to avoid that the automatic algorithms of Change Detection can consider "change" the not perfect overlap of the data.
We have georefered IMG2 and IMG3 having as reference IMG1 and IMG4 on IMG5 using a series of manual GPC as edges of buildings, roads intersections, and many others with auto-correlation algorithms.
We have used a total of 20 GPCs that have manually been selected, and many other points automatically noticed through AutoTie with Affine algorithm (with threshold RSM planned to 0.5) and a range of non inferior reliability to the 80%.

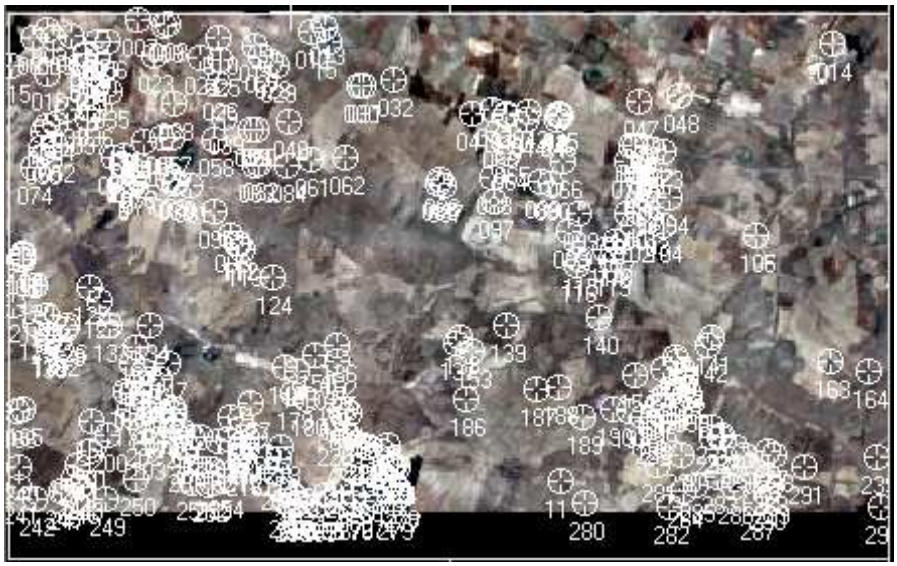

Fig. 1 GCP and Co-registration

3.3 Control and evaluation

A visual control of the results of the operations until here turns allows to avoid great discrepancies. In the next images we have shown the gotten results also in the non good cases.

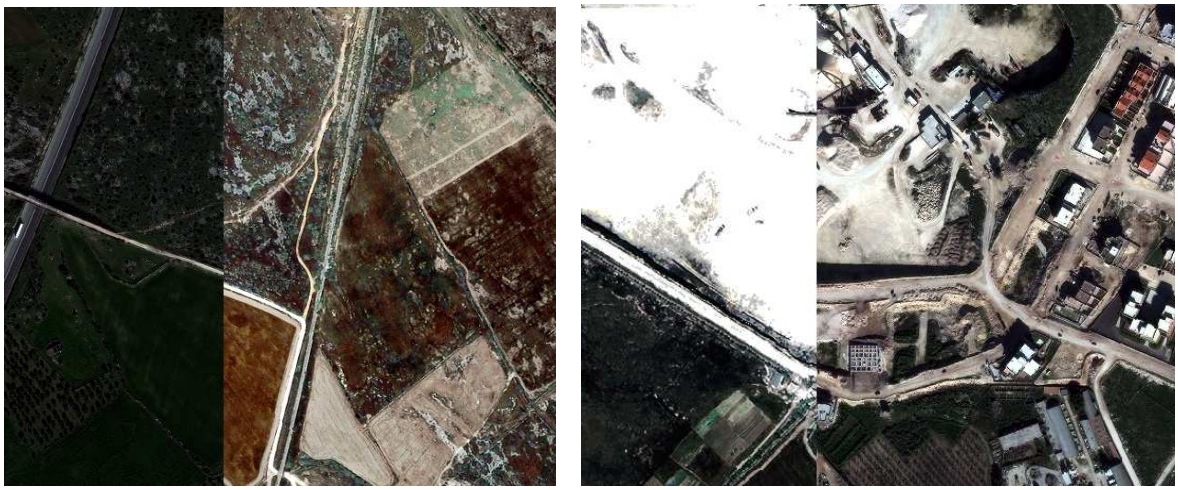

Fig. 2 Results of co-registration

3.4 Resampling and cut

IMG2 and IMG3 as well as the IMG5 result to have a greater spatial resolution in comparison to IMG1and IMG4 respectively. It also needs from this point of view to homogenize the situation, and therefore the images will suffer an operation of resampling through Cubic convolution algorithm to get a resolution of pixel common to all the five images.
The images IMG1, IMG2 and IMG4 have been then cut to eliminate the external zones.

3.5 Color Matching

Now we can consider the images homogeneous from a spatial point of view, but not yet from a radiometric point of view. To correct this further discrepancy we have used a Histogram Matching among the images.
The selected automatic operation returns quite good results after setting of few parameters.

4. CHANGE DETECTION

The images are now homogeneous, and it is possible effect the analysis of Change Detection. Loading the couples of images and launching the first iteration of process of Change Detection with default parameters, the result doesn't allow an immediate analysis because it finds too many changes.

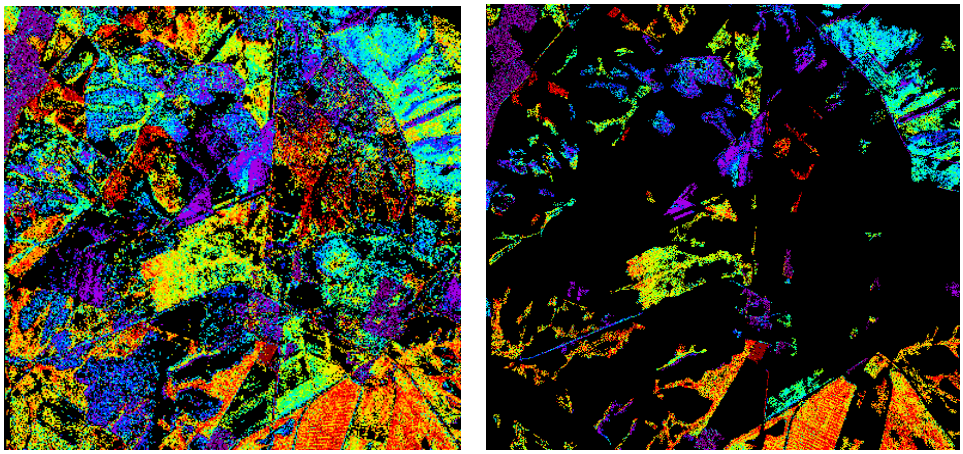

Fig. 3 Change detection before and after filter application

The setting of parameters and filters with different iterations allows the individualization of the meaningful changes.
With the calibration of spatial filters such as area, imposed to notice only the changes above 1000 adjoining pixels and a 70% variation threshold, we have gotten a good reduction of the noise.
Following we show some examples both in Alta Murgia and in Manfredonia, where the Change Detection has given good results.

Fig. 4 Good detection of Change in Alta Murgia

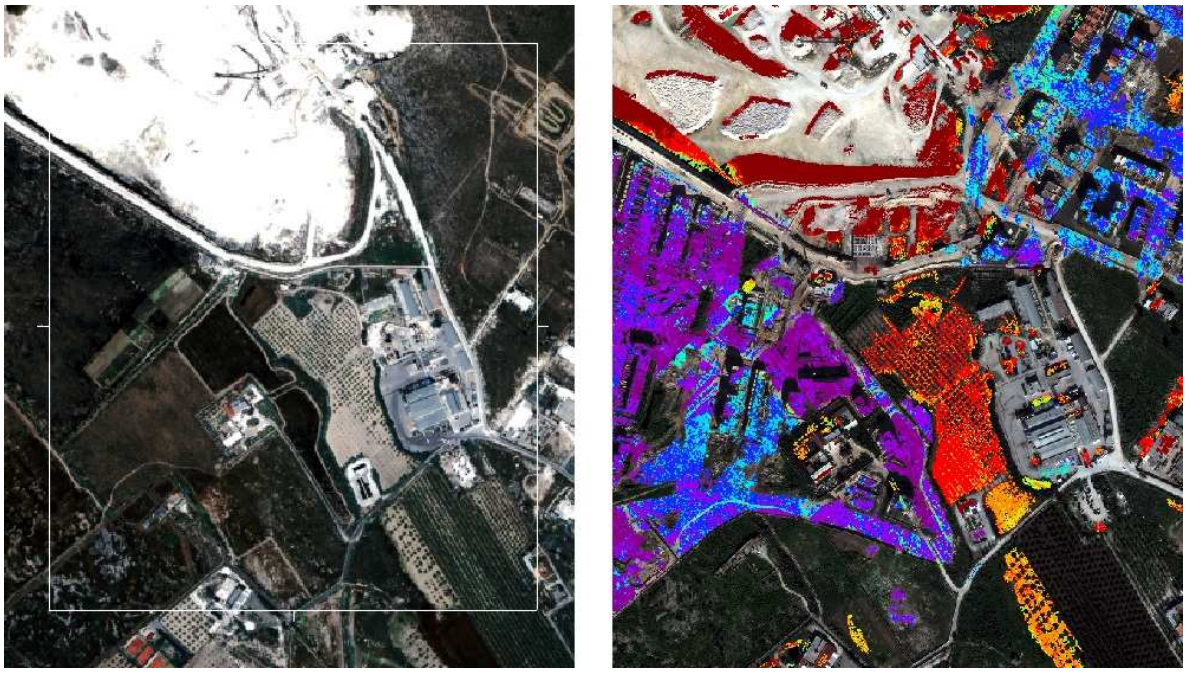

Fig. 5 Good detection of Change in Manfredonia

5. ANALYSIS OF THE RESULTS

The automatic elaborations have shown achievable possibility with the procedures of Change Detection with images not conventional also free available online.
The automatic procedure has allowed to locate quickly many points of change in the territory, but in some occasion it has given also some "false positive".
We have verified that the previous operations of calibration and synchronization of the data allow to improve the achievable results, already reducing the error predictable, due to the same procedure of comparison pixel for pixel realized on heterogeneous images.
Obviously if we had conducted the experimentation with multi-temporal images coming from the same sensor we would have reached more comforting results, but we want to underline that, also with low cost data, it is possible to effect a screening of the changes, except to go to investigate more punctually in the zones individualized by the first analysis of Change Detection.
Such method results interesting in those zones where, because of emergencies, is had to appraise the changes intervened on an area where historical satellite images are not available.
The present study has used images with 1 mt. spatial resolution ; it will be interesting in the future to appraise the obtainable results with a series of greater resolution images, verifying how much the automatic algorithm of Change Detection is sensitive to the resolution in entry.
We have used in fact also the images WorldView II to the resolution of 1 meter instead that native of cm 50.
In the next future we plan to use these new images of WorldView II exploiting the 8 bands furnished by the sensor and it will be able in fact the results to make even more interesting really in those variations of the territory more hardly visible to the human eye.

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BIOGRAPHICAL NOTES

Teacher of cartography and geomatics from 1983. President of the section in Bari of the SIFET Association that pick up the students and the experts of the sector at a local and regional level with activity of seminars, courses and conferences. He has partecipated in the national and international conferences of the scientific associations of the sector - ISPRS (Amsterdam 2000 - Wien 1996), AIC (Ottawa 1999 - Stockolm 1997), FIG (Brighton 1998), ASITA (ITALY), with presentation of contributions and original papers. Titular of convention of search with Italian Corporate (ASI) and undertaken builders in the field of Terrestrial Survey (GPS) and Photogrammetry either for Cartography either for special surveys for the enviroment and the territory, furthermore for GIS (Geographic Information System, etc.
- FELLOW member of R.I.C.S. (ROYAL INSTITUTION OF CHARTERED SURVEYORS).

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