Processing of Satellite Images for Evaluation of Environmental Changes in Time with CHERS

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Abstract

In the paper we present the application CHERS, which is in gridification stage in framework of ***SE-GRID-SCI*** *project. The application aims processing of series in time of satellite images of the same area. Processing of images consists in filtering of noises in spatial and time domains, trend analysis of each pixel in time, multiplication of images using interpolation, and production of video-clips that represent the evolution in time of environmental conditions as level of vegetation, humidity, pollution and other indicators that may be measures using different bands of satellite imagery. We use libraries like LibTIFF to extract bitmaps from image files of specific formats. We use routines developed in C to process bitmap files. At the end we use images of false colors to statically represent the parameters obtained by trend analysis of variations of each individual pixel; and packages for conversion of BMP suites into AVI to produce video-clips for dynamical representation of environmental changes. Considering the complexity of processing multi-layer satellite images and the need to combine a great number of images of the same area received in different days of the year for many years, use of grid to distribute calculations in several processors would help to shorten the processing time. Combination with platforms as ESIP may help to automatize further the process through automatic downloading of satellite images from the Internet.*

Introduction

Environmental studies lead earlier or latter to the need of evaluation of time variations of different environmental parameters. In our past works for the analysis of environmental situations in critical areas, as in Ohrid-Prespa system [1] and in Adriatic Sea coastline [2], we have used satellite images to evaluate changes in time of environmental conditions. In both cases there are serious damages created by each part to the other: humans to nature and nature to humans. If Micro Prespa Lake was damaged as result of human agricultural activity, in Adriatic coast considerable sections of the beach and buildings are lost as result of advancement of the sea. There are even strange examples of adaption of humans towards the “aggression” of the sea, as in the case presented in Fig.1, where the basement of a drilling machinery, once hundred meters away from the beach and now covered by waters, is used as support for a platform for economic activity.

Fig.1. Areas covered by advancing sea in Adriatic Coast (Left image: cyan area – advancing sea, yellow area – delta river increased, red line – tectonic fault)

The use of Landsat images from seventies, eighties and nineties permitted a clear identification of environmental parameters' variations in time in endangered areas, leading to discovery of even potential correlations between tectonic activity and environmental changes (Fig.1).

Remote sensing continues to be more and more important for the evaluation of time variations of environmental parameters, particularly important because of global warming and increase of human activity [3]. Intense work is done for facilitation of satellite image processing from non-IT experts as in [4], [5].

In order to improve the understanding of environmental changes we considered processing of satellite imagery data seen as 3D matrices of pixels, with time as one of dimensions.

Using images received in different days for the same area makes possible the evaluation of seasonal and long term environmental phenomena, using different wavelengths for different environment parameters. Application of interpolation in time and use of filtering techniques may permit smoothing of analyzed 3D functions, elimination of noises and production of qualitative videos presenting time variations of environment conditions (Fig.2).

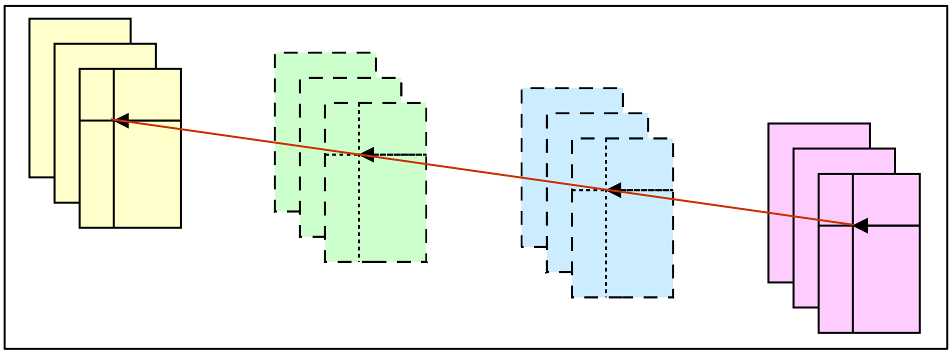


Fig.2. Schema for processing of videoclips

For a complete analysis of environmental changes detailed data processing may be required. As a first approach we focused on trend analysis in time of individual pixels, which permitted a static presentation of the character of changes (Fig. 3).

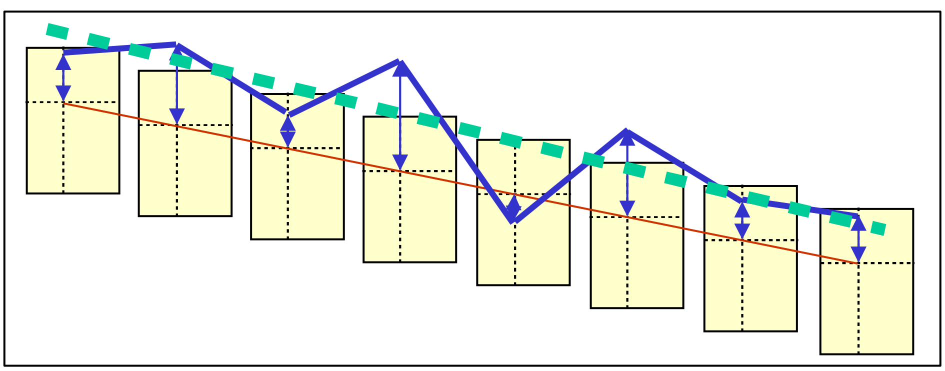


Fig.3. Schema of trend analysis in time for individual pixels

The follow-up of this idea will require the application of more complex methods as:

- Spectral/entropy analysis in space-time domains
  - Filtering and correlation/classification procedures
  - Identification of specific patterns and their evolution
  - Identification and morphing of water bodies' shore lines

Processing of suites of satellite images may require huge calculation power, especially when high resolution is required and processing algorithms are complex, as in cases of identification of certain areas using pattern recognition, or identification and morphing of borders of water bodies.

CHERS framework

CHERS was designed as an application framework that would permit users to perform complex image processing in space-time domains.

The principal architecture of CHERS is given in Fig. 4.

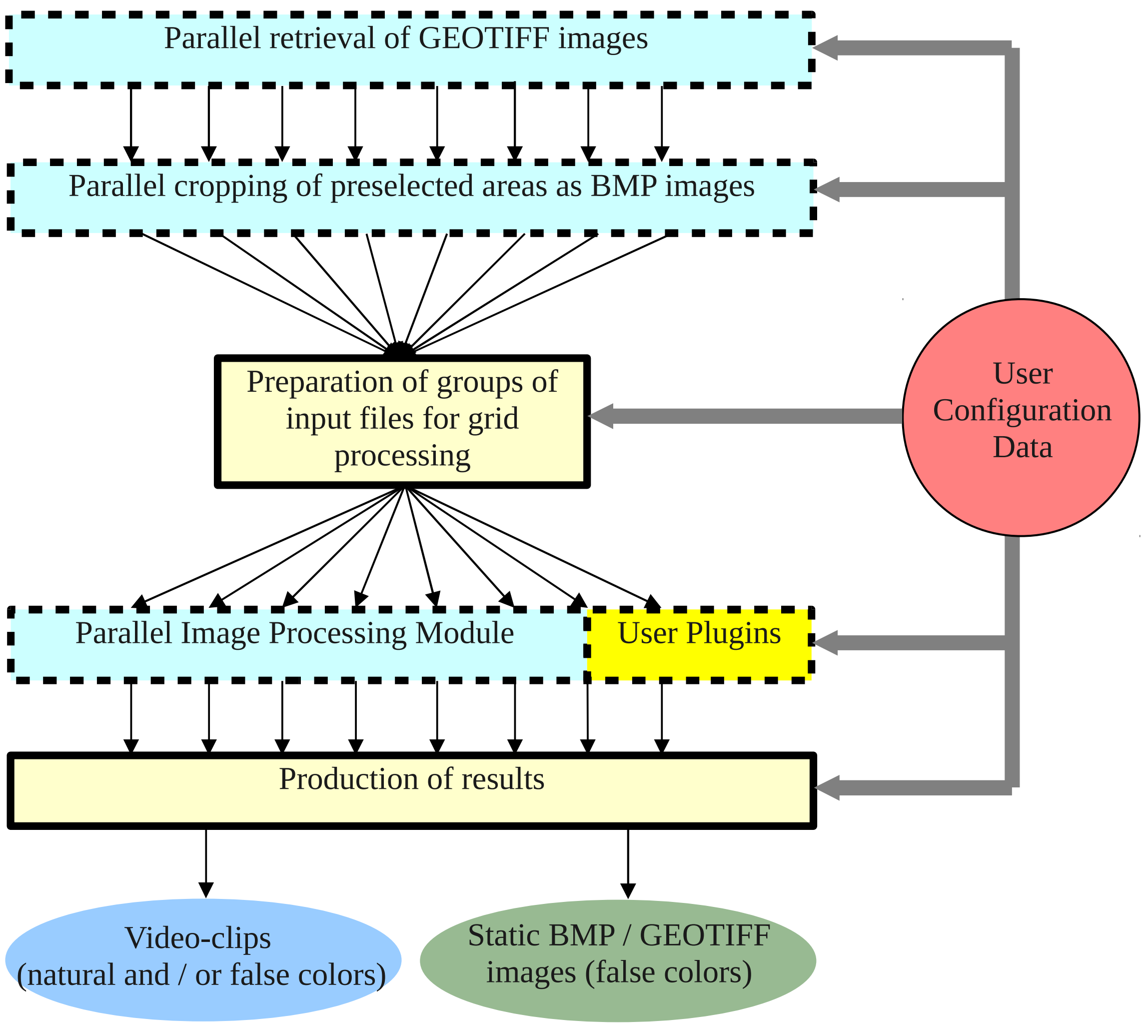


Fig.4. CHERS Framework. Dotted blocks in cyan may be run in parallel

In the CHERS framework the retrieval of GEOTIFF images may be achieved in two ways:

- special routines that must download images from Internet repositories, with probably preprocessing of images to produce GEOTIFF (images of MODIS for example are found in HDF format)
- through interfacing with special portals as ESIP [6]

Extracted bitmap images, cropped to cover a specific area, may require a unique process to be converted in groups of data files suitable for grid processing. During this preparatory process, special procedures may apply to

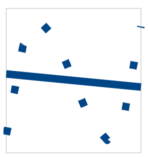
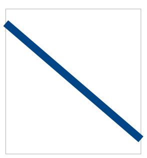
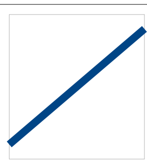
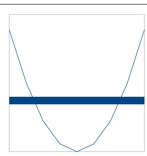
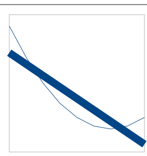
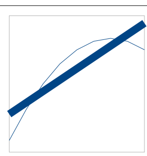
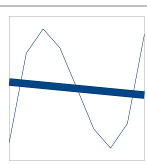
- distinguish areas covered by clouds or snow
- peripheral parts of canvases not covered by images' layers

– calibration of images
– insertion of calibration marks to be used in the final processing stage

Processing Image Module may be completed with PlugIns developed by users for specific needs.

Analysis of pixel variations using trend analysis

As a first step we focused in static analysis of time variations of each pixel. Trend analysis with polynomials of different orders permits identification of tendencies and how these tendencies are changed in time:

Polynomial degree	Plot	Environmental situation as presented by trend analysis
0		Linear trend almost constant. Strong variations in the real situation. See also the case of polynomial order 3.
1		Stable decreasing situation presented by linear trend. Second and third order polynomial terms are insignificant.
1		Stable increasing situation presented by linear trend. Second and third order polynomial terms are insignificant.
2		Reversal situation. Linear trend gives wrong information – no changes. Significant value of polynomial term of second order induces the presence of a reversed situation.
2		Decreasing situation with tendencies for stabilization. Linear trend gives wrong information. Significant value of polynomial term of second order.
2		Increasing situation with tendencies for stabilization. Linear trend gives wrong information. Significant value of polynomial term of second order.
3		Strong variations in the terrain, presence of significant polynomial terms of third order. Linear trend gives wrong information – slow changes.

We used false color images, considering as R, G and B colors normalized values of different polynomial coefficients. Areas with specific development tendencies as described above may be distinguished though specific colors. Combination of colors may depend to the character of the environmental task to be solved. In one example we used combination of coefficients of first order of the linear trend and of second order of the quadratic trend, producing a palette as in Fig. 5.

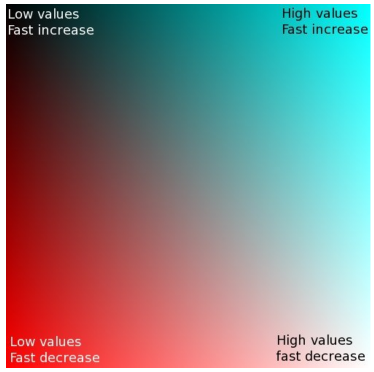


Fig.5. Palette with combination of
Red (decreasing gradient) and Blue-Green (averages)

Application of this palette for the analysis of time variations of normalized vegetation index (NDVI) for MODIS TERRA images of the period August-September 2000-2009 is presented in the Fig.6.

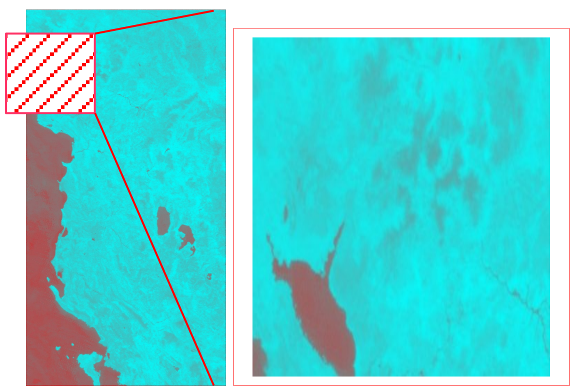


Fig.6. NDVI trend analysis of MODIS TERRA images

In Fig.6 right it is presented a section of processed area. Reddish patch in left-lower part of the image is Lake of Shkodra (NDVI is not used for water bodies, nevertheless reddish color of both sea and lake waters is a sign that something is changing there). Dark patches in the center of the section represent top mountain areas where vegetation is low and has changed little during the period 2000-2009. Light cyan color areas are covered with vegetation that has increased from year to year (this is only a methodical interpretation, real interpretation requires calibration of images that is not performed).

Usage of video-clips to present time variations of environment

Video-clips based on suites of satellite images offer a dynamic view of the change in time of environmental situations, instead of the static one based in trend parameters.

The simplest case is production of the video introducing extra video frames through simple interpolation. This is effective in cases when colors of pixels vary gradually, as in case of vegetation variations.

Interpolation may give unsatisfactory results in cases of variations of borders of water bodies, for example lakes or rivers shorelines – simple interpolation would blur the contours of such objects. In case of interference bands obtained from SAR images, for example, simple interpolation in time of pixel values would deform the whole view. Solution would require identification of the same specific areas in different images and calculation of morphing from one instance of the area to the next one.

As the first step we focused in simple interpolation, experimenting with enhanced images of NDVI in false colors. Using the same MODIS TERRA images as in the case of trend analysis, the suite of NDVI images that serves as basis for the production of the video-clip is given in Fig. 7.

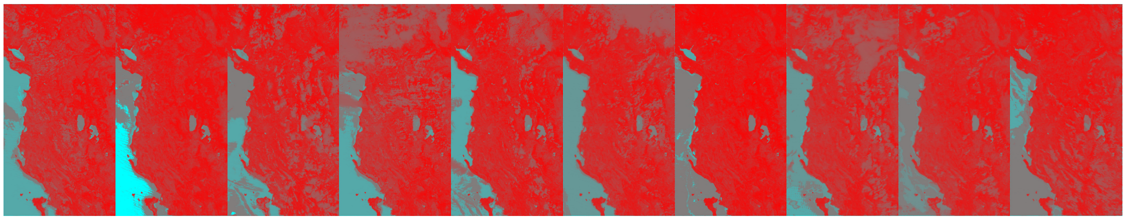


Fig.7. Suite of NDVI images in 2000-2009

Simple packages as easyBMPtoAVI may be used to produce the video-clip in this case.

Conclusions

Analysis of satellite images of the same area, taken in different moments, permits the visual presentation of environmental changes. This can be done in static and dynamic ways. Static presentation of environmental variations can be achieved constructing images of false colors using as Red, Green and Blue color values for each pixel specific coefficients of trend polynomials. Proper combination of colors permits an easy identification of areas with different trends of variation.

Dynamic presentation of variations in time is possible producing video-clips based on the suite of satellite images. Simple interpolation may be useful in case of areas with blurred contours. Instead, for areas with clear contours or as combination of narrow bands interpolation may give deformed view of the process. Identification of specific areas and morphing from instance of the area to the next one would be a solution.

Considering that a single 2-band MODIS image may occupy up to 150 MB of memory, processing of numerous images using complicated mathematical algorithms requires huge storage and processing capacities. Use of grid systems may help to facilitate the storage of satellite data and reduce the calculation time.

CHERS is a application framework that allows users to carry out calculations in space-time domains of satellite images for the analysis and presentation of environmental changes. CHERS may be combined with tools as ESIP for better performance and interfacing.

Continuation of the work will focus on completion of CHERS modules for basic image processing and creation of the possibility for inclusion of user plugins.

Acknowledgement: The final publication is available at www.springerlink.com

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