A NEW USER-CENTERED PARADIGM FOR MULTITEMPORAL SAR DATA REPRESENTATION

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1. ABSTRACT

In this paper we present the Multitemporal Adaptive Processing (MAP3) paradigm devoted to the definition of new multitemporal, user-oriented products. MAP3 is organized in three blocks of activities dealing with pre-processing, adaptive processing and representation. Experiments performed on different scenarios testify the reliability of the proposed paradigm and its independence from both sensor and scene.

2. INTRODUCTION

Multitemporal SAR is a very powerful and attractive technique for environmental monitoring and the study of dynamic phenomena. However, the analysis of a series of images introduces relevant challenges regarding the extraction, interpretation and representation of information.

In this paper we present the Multitemporal Adaptive Processing (MAP3) [1] framework for the definition of a new family of multitemporal, user-oriented products we called *Level 1*α because they conceptually are an evolution of Level 1 products but not properly Level 2 ones.

MAP3 defines a reliable processing which should allow the achievement of a set of comparable images and the best level of interaction between the user and the machine during the decisional phase.

A literature review about multitemporal SAR issues showed the necessity of building general and analyst-driven frameworks restoring the centrality of the users in the processing chain which is usually neglected at advantage of a (often excessively) refined mathematics. Hence, the design of a new framework should be guided by the six properties of reproducibility, automation, adaptability, reversibility, visualization and interpretation. This ensures the suitability of the proposed framework with operative scenarios.

The paper is organized as follows. In Section 1, the MAP3 paradigm is briefly discussed. Multitemporal Level 1α are presented in Section 4 with experimental results concerning datasets acquired on semi-arid Burkina Faso and temperate regions. Conclusions are drawn at the end of the work.

3. MAP3 PROCESSING CHAIN

MAP3 can be organized in three blocks of activities (see the block diagram in Figure 1) dealing with pre-processing (coregistration, calibration and despeckling) adaptive processing and representation. The design of the blocks pointed to the simplicity, minimizing the operations necessary to obtain the products, and to the availability of the algorithms. Innovation was provided in the cross-calibration step in which we introduced the Variable Amplitude Levels Equalization (VALE) method presented in Section 3.3 [1].

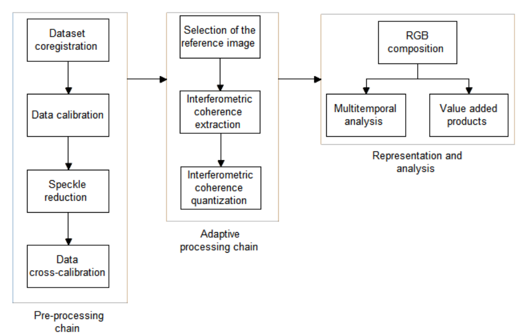


Fig. 1: MAP3 block diagram.

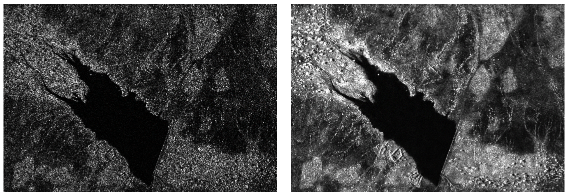
In the following sections we briefly discuss the processing chain depicted in Figure 1.

3.1. Calibration

One of the major challenges of the processing chain is to create a series of radiometrically comparable images. In this work we processed time series of COSMO-SkyMed and TerraSAR-X Single Look Complex images, for which the sigma naught can be evaluated applying a calibration factor calculated from ancillary data.

3.2. Despeckling

In multitemporal analysis despeckling has a key importance since the effects of speckle presence should alter the discrimination of the features along the temporal axis. In this work we employed the multitemporal De Grandi filter which allowed a significant speckle reduction with no loss in spatial resolution (see Figure 2).



(a) (b)

Fig. 2: Laaba basin, Burkina Faso, intensity map before (a) and after (b) the application of the De Grandi filter.

3.3. Cross-calibration

In order to combine the images of the time series in a RGB color space it is necessary that data are expressed in a common scale with a number of levels (usually 256) suitable with human visual perception. In the past literature (see [2]) this problem was solved with a percentile-based histogram clipping. If the scene is subject to extreme variation (as happens in semi-arid regions) this method could lead to an alteration of the amplitude ratios between the images of the time series and then to a misclassification of the relevant features of the scene.

The VALE method ensures that the histogram clipping is performed at the same amplitude level for all the elements of the time series. Under the hypothesis of perfectly calibrated data, VALE guarantees the balance of the channels involved in the RGB composition.

To prove this claim consider the scatter plot shown in Figure 3 in which the statistics of ten sample homogeneous areas occupied by trees taken in two different acquisitions are shown. Trees are almost stable object, thus their response is expected to be stable. This happens if the VALE method is applied. But it does not if the percentile clipping previously proposed in literature is used. This leads to an unbalance of the final RGB composition.

3.4. Adaptive processing

In order to evidence a certain image feature an appropriate reference scenario has to be defined. In semi-arid regions, it occurs at the end of the dry season (usually in April), when terrains are almost completely bare and the ponds are empty [3]. Hence, the detection of the features of interest is possible by comparison of a test image with the reference one.

In temperate areas the selection of the reference situation is dependent on the the application. For example, if summery crops has to be monitored, a reasonable choice for the reference image should be the adoption of a wintery acquisitions.

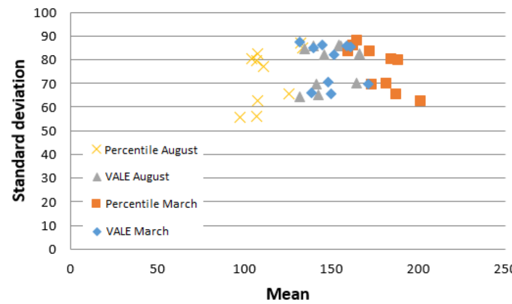


Fig. 3: Scatter plot mean VS std of ten homogeneous trees samples taken in two different acquisitions.

The usage of the interferometric coherence as third band allows to discriminate the presence of man-made surfaces.

4. MULTITEMPORAL RGB PRODUCTS

4.1. Application in semi-arid environment

The multitemporal products here presented have been obtained loading on the red, green and blue band the coherence map, the test image and the reference image, respectively. The band-color association eases the association between the displayed colors and the physical characteristics of the scene. In Figure 4, the test image was acquired in August and loaded on the green band. The growth of vegetation provokes an enhancement of the backscattering with respect to the reference scene (April). Hence, the green band amplitude is dominant with respect to the red and blue bands. Areas covered by seasonal surface water appear in blue because in the wet season the basins are filled up by intense rainfalls and

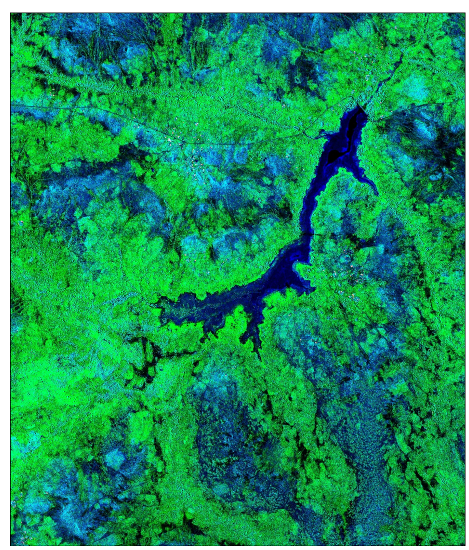
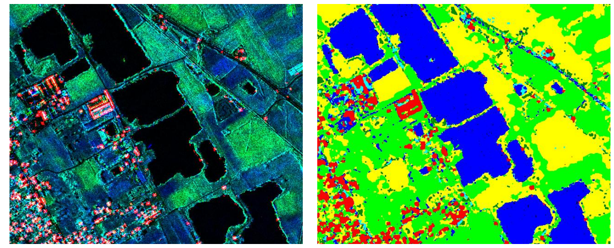


Fig. 4: Burkina Faso, COSMO-SkyMed Level 1α product. R: coherence map, G: August 2010, B: April 2011.

Fig. 5: Ciró Marina, Italy, TerraSAR-X Level 1α product extracted from a series of 35 images.



(a) (b)

Fig. 6: Caserta (Italy): Level 1α product (a) and six classes ML classification (b): Water (Blue), Grass (Green), Tanks (Cyan), Urban (Red), Summery crops (Yellow), Woods (Dark Green).

the corresponding backscattering (green band) is significantly weaker than to that of the reference dry situation (blue band). Persistent water appears as a black area within the basin, because of the low electromagnetic response both in the dry and in the wet season.

4.2. Applications in temperate areas

In this section we want to highlight the independence of MAP3 from both sensor and scenario.

The solution presented in Figure 5 has been built processing a set of TerraSAR-X stripmap acquired on Calabria, Italy. The reference image (blue band) is an acquisition of January 2010, while the test image (green band) has been acquired on April 2008. In this representation, the behavior of the relevant feature of the scene is the same of that previously analyzed for the Burkina Faso scene. In particular: permanent water surfaces (e.g. the sea) appear as dark areas because of the low response of all the involved channels; urban areas are represented as bright areas due to the high contributions of both intensity and interferometric coherence; cultivated areas have a color that depends on the type of cultivation. However, because of the high degree of anthropization,in this case the agronomic interpretation is not trivial and needs to be supported by specific expertise.

In Figure 6 a Level 1α product obtained processed a multitemporal series acquired on Campania, Italy and its six classes maximum likelihood classification is depicted.

5. CONCLUSIONS

Multitemporal SAR analysis is a powerful and attractive technique for environmental monitoring and planning. It introduces nontrivial issues relative to data calibration and their representation. This technique has been widely explored in the past literature but never coded in all its aspects. In this paper, we formalized the problem introducing the MAP3 framework, which, mixing state-of-art techniques and a novel cross-calibration method (VALE), brings to the extraction the Level 1α products, which are characterized by a context-adaptive nature unlike the already available Level 1 products.

The proposed framework is organized in three blocks of activities dealing with pre-processing (coregistration, calibration, despeckling), adaptive-processing and representation. MAP3 is robust and flexible; in fact, on the one hand it can be replicated in different climatic zones and for different sensors. On the other hand the techniques embodied in each block can be substituted by others present in literature or implemented ex novo. Moreover, other blocks can be inserted in the processing chain in order to adapt MAP3 to the specific application.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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