MODEL-BASED MULTITEMPORAL SAR RGB PRODUCTS FOR LAND AND WATER MANAGEMENT

Donato Amitrano[(a)], Francesca Cecinati[(b)], Gerardo Di Martino[(a)], Antonio Iodice[(a)], Pierre-Philippe Mathieu[(b)], Daniele Riccio[(a)], Giuseppe Ruello[(a)]

[(a)]University of Napoli Federico II, Department of Electrical Engineering and Information Technology, Via Claudio 21, 80125, Napoli, Italy, Emali: {donato.amitrano, gerardo.dimartino, iodice, dariccio, ruello}@unina.it

[(b)]European Space Agency, ESA ESRIN, Via Galileo Galilei, 00044 Frascati (Rome), Italy, Email: {francesca.cecinati@bristol.ac.uk, Pierre.Philippe.Mathieu@esa.int}

ABSTRACT

In this paper, we present an innovative framework for RGB composition of multitemporal SAR data. The proposed products improve users' experience with data enhancing interpretability and allowing for information extraction using simple techniques. The characteristics of the RGB products are illustrated through examples in which their suitability with several applications is highlighted.

1. INTRODUCTION

The use of synthetic aperture radar (SAR) data in applications is today still limited due to the lack of appropriate, end-user oriented data representation and information extraction algorithms that are repeatable and transparent in terms of free parameters to be set.

In this paper, as already expressed by several authors (see as an example [1], [2], [3]) we claim the necessity to restore users' centrality in remote sensing data analysis. The mean we use to achieve this objective is the introduction of two new classes of RGB SAR products obtained via multitemporal processing. The principal characteristics of the proposed products are the ease of interpretation and the possibility to be processed with simple, end-user-oriented techniques [4]. The proposed approach aims to definitely fill the gap between the academy and the applications. The rationale is to provide ready-to-use images, in which the technical expertise with electromagnetic models, SAR imaging, and image processing has been absorbed in the products formation phase. In such way, the idea that SAR images are too complicated to be interpreted and processed without a high technical expertise in order to extract physical information is overcame.

The paper is organized as follows. In Section 2, the outline of the proposed framework is briefly discussed. RGB products are presented in Section 3. Some applications are addressed in Section 4. Conclusions are drawn at the end of the work.

2. METHODOLOGY

Dealing with SAR data, some of the problem to be addressed for improving image interpretability (especially for non-expert users) are the following:

- Grayscale displaying: humans usually deal with color images, which lead to a fast searching and comprehension of data;
- Speckle: SAR images are corrupted by noise due to random combination of sub-resolution elements scattering. This phenomenon prevents the correct interpretation of data and is also a source of distortions of the information content;
- Image pdf: SAR images are characterized by an exponential pdf, which prevents their displaying on a linear scale;
- Radiometric distortions: dealing with time-series data, radiometric calibration is mandatory for a correct evaluation of the scene dynamics.

The role of SAR community should be to mitigate these problems, getting data closer to the end-user community. The proposed processing chain has been designed with this objective, i.e. to output products having the characteristics of interpretability and manageability necessary to be attractive for the end-user community. The objective is to lower the expertise required to manage and interpret SAR products. This should get SAR data closer to end-users and make them able to interpret correctly images and perform basic operation on data only using colors, which is the common practice to interact with data acquired in the visible spectrum.

The proposed framework consists of three stages [2]: i) a pre-processing phase aimed at geometrical, temporal, and radiometric calibration, ii) a decomposition of the image information on a proper base and iii) a fusion of the three channels. It has been designed in order to satisfy the requirements of reproducibility, automation and adaptability and is characterized by two branches providing two categories of products we named as Level-1α [2] and Level-1β [5].

These products have a different rationale. Level-1α products are bi-temporal, i.e. built using two intensity images and their interferometric coherence. Therefore, they are particularly oriented toward change-detection applications.

Level-1β products aim at providing synthetic information about a time-series. In fact, their bands are constituted by temporal variability indicators (mean backscattering, time-series variance, mean interferometric coherence and time-series saturation index) combined in a unique RGB frame. Therefore, in this case the objective is to identify features basing on their characteristic dynamics.

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The main characteristic of these products is that the association color-object is stable for variations of the scene and of the climatic condition, given a proper selection of the images involved in the RGB composite. The semantic stability allows both Level-1α and Level-1β products to be effectively exploited in applications.

3. PRODUCTS

In this Section, the output of MAP3 framework is presented trough examples highlighting the linkage between the map color and the scene objects.

As for Level-1α products, a particularly significant example concerns semi-arid regions. In these areas, there are two seasons: a long dry season, and a short wet season, characterized by severe rainfalls [6]. At the peak of the dry season, instead, the environment is almost completely dry. Therefore, this condition represent a favorable reference situation to evaluate the scene dynamic in a change-detection environment.

In Fig. 1, a Level-1α composition concerning a rural area of Burkina Faso is depicted. The dry season reference image has been loaded on the blue band. The green band is reserved to an image acquired during the wet season. The interferometric coherence is loaded on the red band; it is useful to identify stable targets (buildings).

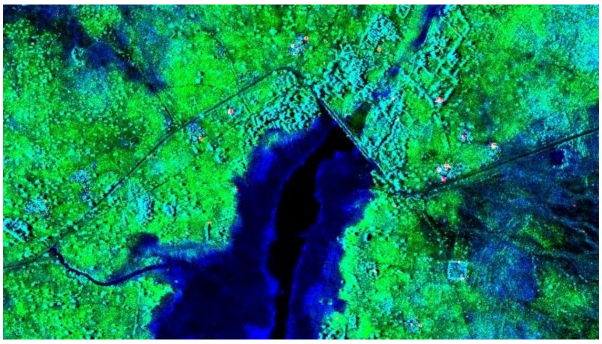


Figure 1. Burkina Faso, Level-1α product. Reference image (blue band): dry season image. Test image (green band): wet season image.

The aforementioned band combination is particularly favorable for the human photo-interpreter, since it allows for the immediate identification of features rendered in natural colors, such as vegetation (displayed in green, due to volumetric scattering due to plant growth in wet season), and water (displayed in blue due to the presence of water in the basin in the wet season). However, this is an image in false colors; therefore, the natural palette rendering is guaranteed only for some objects. As an example, bare soil is rendered in Prussian blue, due to the backscattering balance of the two acquisitions involved in the RGB composition.

As stated above, the principal characteristic of MAP3 products is the semantic stability of the product. In other words, if the scene varies, the association color-object is expected to be stable.

To prove this claim, consider the scene depicted in Fig. 2. It concerns the city of Castel Volturno (Italy). Nevertheless the climatic condition and the scene structure is completely different with respect to the one previously analyzed, map colors are associable to the same objects. In fact, as an example, green represents growing crops. Prussian blue is associable with bare soils. Black with permanent water. Bright targets are representative of buildings.

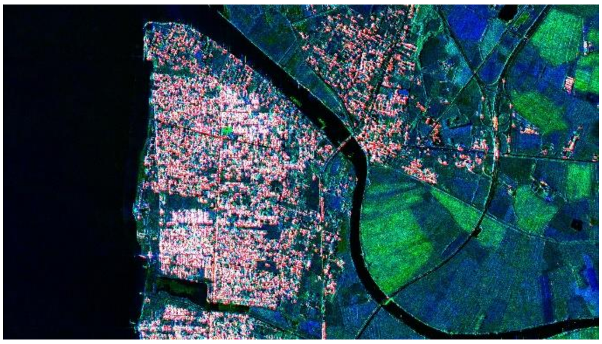


Figure 2. Castel Volturno (Italy), Level-1α product.

Dealing with semi-arid regions the band combination previously introduced (i.e. red: interferometric coherence, green: test image, blue: reference image) allows for rendering in natural colors the most important features of this environment, i.e. water and vegetation. However, in temperate environments, this leads to an image in which there is a high blue content on land surfaces, which could be judged misleading. To avoid this, it is possible to exchange the role of the interferometric coherence and of the reference image, as shown in Fig. 3, in order to retrieve a significant red component on terrains and moving blue contribution to the urban area. In such way, an image closer to the natural color palette is obtained.

Figure 3. Castel Volturno (Italy), Level-1α product. Exchange of the role of the interferometric coherence and reference image has been made to obtain an image closer to the natural color palette.

As stated in Section 2, Level-1β products aim to summarize the information of a time series in a unique RGB image, providing a useful support for classification.

In Figure 4, a Level-1β product of the city of Castel Volturno is shown. The selected band combination is red: time-series variance, green: mean backscattering, blue: combination of mean interferometric coherence and saturation index. Also in this case, this combination allows for rendering in natural color some features (such as grasslands and sea), while for the others, the restituted colors depend on the physical characteristics of the imaged object. As an example, growing crops are rendered in a yellowish color due to a significant contribution of the variance. Buildings are represented in cyan due to their high and stable backscattering and high phase stability.

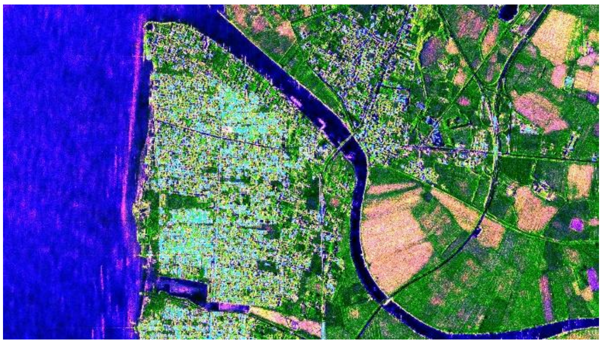
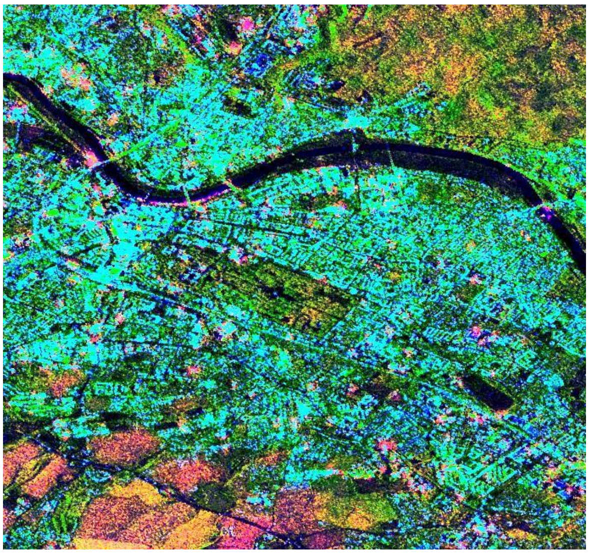


Figure 4. Castel Volturno (Italy), Level-1β product.

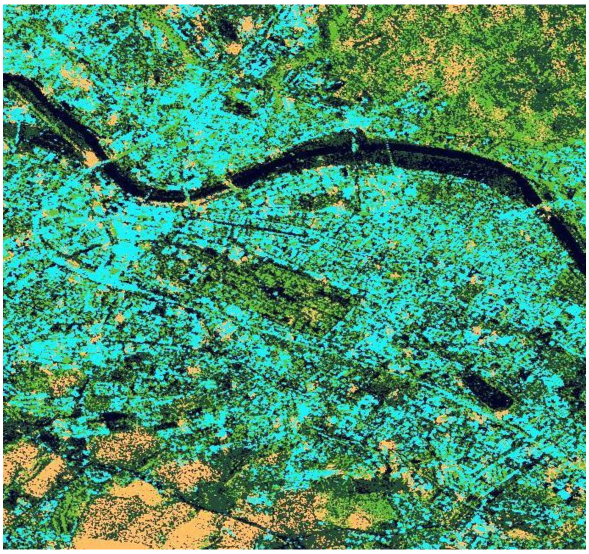
One of the principal characteristics of the MAP3 framework is the modularity. In other words, the basic schema proposed in [2] can be enriched by some processing block to obtain higher level products. Here, we propose a self-organizing map (SOM) clustering [7] in order to reduce the dimensionality of the input product. In the same time, the clustered image is enriched by a basic semantic, represented by a verbal attribute recalling the class color.

An example of such processing is reported in Fig. 5. In particular, in Fig. 5a, a Level-1β product concerning part of the city of Dresden is depicted. In Fig. 5b, its 5-class land cover map obtained through SOM clustering is reported. The most interesting property of this neural net is the possibility to preserve the chromatic content of the input RGB product. In fact, the reader should appreciate how these two representations appear very similar. This allows for an immediate semantic transferring from the input RGB product to the output classified product.

As stated above, the classified product gains a basic semantic through the SOM which allows for identifying image features through a verbal query of the color attribute. In this case, the following association color/cluster-object can be made: cyan-built up, orange-growing crops, black-water/weak scatterers, light green-grasslands, dark green-woods.



(a)



(b)

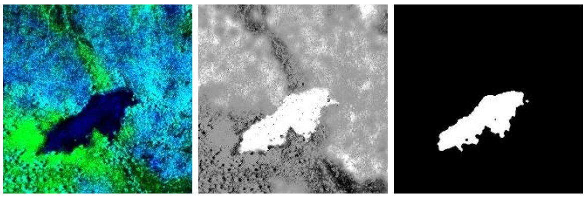
Figure 5. Dresden (Germany), (a) Level-1β product, and (b) 5-class land cover map obtained through SOM clustering.

4. APPLICATIONS

Both Level-1α and Level-1β products are extremely versatile and can be exploited in several applications such as water body extraction [8], classification [4] and features extraction [9].

Level-1α products allows for reasoning using very simple tools like band ratios [8], [10]. This can be done, as an example, dealing with the extraction of shorelines of small reservoirs in semi-arid regions. In this case, a band ratio enhancing image features with a high blue content can be designed to build a mask of the considered basin.

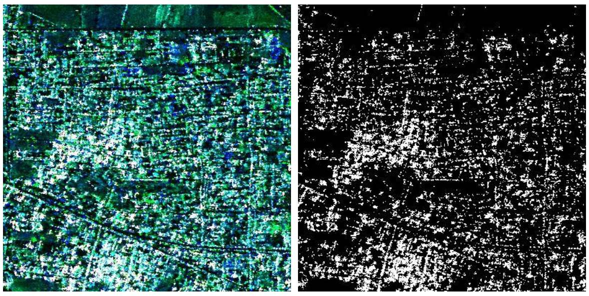
This process is depicted in Fig. 6. In particular, in Fig. 6a, the input Level-1α product is depicted. The water index map is shown in Fig. 6b. Finally, the basin mask can be obtained through the selection of a suitable threshold, as shown in Fig. 6c.



(a) (b) (c)

Figure 6. Basin extraction using a band ratio: (a) input Level-1α product, (b) water index and, (c) basin mask after thresholding of the water index map.

A similar reasoning can be made for the built-up feature [10]. In this case, an index exploiting Level-1α products and the properties of high backscattering and phase stability can be designed. An example is provided in Fig. 7. In particular, in Fig. 7a, the input Level-1α product, concerning the city of Triflisco (Italy) is depicted. In Fig. 7b, the building mask obtained by thresholding of the aforementioned index is shown.



(a) (b)

Figure 7. Triflisco (Italy): (a) input Level-1α product, and (b) building mask obtained after thresholding of a suitable index exploiting the properties of high backscattering an phase stability of this feature.

5. CONCLUSIONS

In this paper, we presented an innovative framework for building user-oriented RGB SAR product exploiting multitemporal. These products improve users' experience with data thanks to RGB displaying of image information content and the possibility to use simple techniques for its extraction.

The suitability of Level-1α and Level-1β products in applicative contexts have been demonstrated through examples. In particular, we proposed to use Level-1α products for small reservoir monitoring and building extraction. In both cases, a threshold applied on a suitable index map exploiting the physical properties of the feature as rendered in the RGB product, allows for a quick and reliable extraction of the desired feature.

6. REFERENCES

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