RGB SAR product exploiting multitemporal: general processing and applications

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***Abstract*—In this paper, we present a new framework for the RGB composition of SAR data. The proposed processing chain aims at providing products particularly oriented toward the end-user community, thus characterized by a high degree of interpretability and by the possibility to be processed with simple algorithms for information extraction. The physical rationale of the proposed RGB products is presented through examples highlighting their principal properties. Finally, their suitability with applications is demonstrated through two activities dealing with urban area and land cover mapping.**

I. Introduction

Today, a number of sensors acquiring data throughout the whole electromagnetic spectrum provide a large amount of data allowing for a better understanding of the world we live. However, when acquisitions are made beyond the visible, representation of data is fundamental to ensure the best exploitation of information for human operators, especially in multi-disciplinary contexts.

Remote sensing involves a large variety of professionals with different expertise and background. Therefore, when a processing chain is designed, it is highly desirable that it takes into account that its potential user could belong to the end-user or decision maker communities, in which one of the primary need is to interact with data even at visual level.

Dealing with synthetic aperture radar (SAR) data, one of the issues preventing their diffusion in applicative scenarios is exactly the the high technical expertise required to interpret and process images as they are usually delivered by space agencies and/or data provider. To overcome this problem, we propose a new framework for the generation of SAR RGB composites derived from multitemporal processing [1], [2]. Its aim is the introduction of a user-friendly intermediate product level (in which principal characteristics are the interpretability and the possibility to use simple algorithms for information extraction) between the classic Level-1 and Level-2.

The work is organized as follows. In Section II, the framework for the building of the RGB products is briefly discussed. Products' main characteristics are also illustrated through examples. Applications exploiting these products are addressed in Section III. Conclusions are drawn at the end of the work.

II. FRAMEWORK AND PRODUCTS

The proposed framework, allowing for the building of the new RGB products, have two objectives: i) to generate a set of images geometrically and radiometrically comparable, and ii) to implement a fusion whose output is able to enhance the user experience/interaction with data. The characteristics of the framework allow for building different products depending on the composition of the implemented multitemporal analysis block. In the following, two classes of products, having different characteristics, will be introduced: the Level-1α product class (change-detection oriented), and the Level-1β product class (classification oriented). Both of them aim at creating an intermediate product level between the classic Level-1 and Level-2 products, and at lowering the expertise required to handle data through an user-friendly rendering of the complex scattering mechanisms between the electromagnetic field and the Earth surface.

A. Level-1α products

Level-1α products are bi-temporal images particularly oriented toward change-detection applications. They combine two intensity images. The third channel is reserved to the interferometric coherence, obviously computed exploiting complex data. One of the intensity images plays the role of the reference situation, i.e. the condition with respect changes are evaluated.

The following example is to clarify the rationale of these products. We consider a semiarid environment in Burkina Faso (western Africa). In this area, the climate is characterized by a long dry season (at the end of which the landscape is almost completely dry), and by a short and intense wet season, which favors the growth of vegetation, as well as cultivations and water harvesting [3].

The product depicted in Fig. 1 has been obtained loading on the blue band the reference image. It has been acquired at the peak of the dry season, which occurs,in this area, at the end of April. On the green band, an image acquired during the wet season is placed (we will refer to it as test image). This composition leads to the following interpretation of the rendered colors [1]:

- A balance of the blue and green channels (i.e. a balance of the backscattering of the reference and test images) means unchanged land cover. Bare soils are rendered in a cyan tonality. Permanent surface water is rendered in black;
- The green color identifies areas interested by vegetation growth due to volumetric enhancement of backscattering;

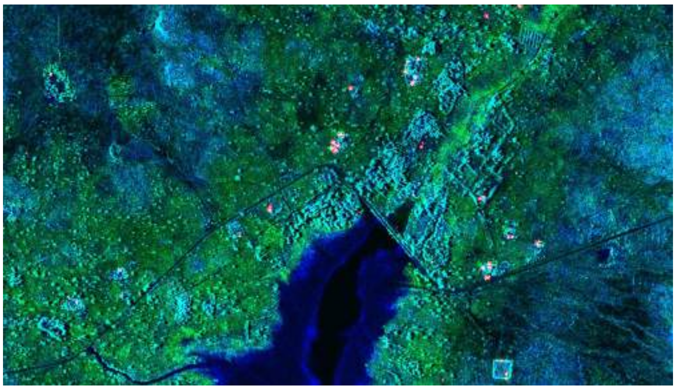


Fig. 1: Burkina Faso, Level-1α product. Blue band: dry season image. Green band: wet season image.

- Pure blue color identifies temporary surface water, i.e. areas covered by water during the acquisition of the test image (i.e. during the wet season). In fact, in this case, the terrain backscattering occurring during the dry season (when the scene exhibits a bare soil response) is dominant;
- Bright targets identify small settlements due to the high contribution of all the bands involved in the composition. In fact, when images acquired with high temporal baseline are considered, only stable targets are expected to exhibit a high interferometric coherence.

This composition allows for rendering in natural colors the most important features of the study area, i.e. water and vegetation.

An important property of Level-1α imagery is the stability with respect to variation of the scene and/or of the climatic conditions. In other words, if the scene is completely changed, the association color-object is the RGB product is the same.

To prove this claim, consider the scene reported in Fig. 2a. It depicts the city of Castel Volturno (southern Italy). In this case, the climate is temperate Mediterranean. The reader should note that the semantics carried by the displayed colors is stable. In fact, green means growing vegetation; a cyan tone means bare soil; the built-up feature is rendered in white; the sea surface is rendered in black.

The image depicted in Fig. 2a has a strong blue component. This could be unpleasant for some users because the blue (except for sea surface) is not so common in true-color optical satellite images. However, this band disposition is particularly well-suited for a semi-arid environment, where it allows for rendering in natural colors water surface, which are particularly of interest due to their scarcity. In temperate environment, where this phenomenon is less important, it could be desirable to retrieve a significant red component on terrains. To this end, the role of the reference image and of the coherence bands can be exchanged. This way, the product depicted in Fig. 2b is obtained, having a rendering closer to the natural color palette.

Level-1α imagery is very well-suited for supervised classification [4], change-detection [5], and feature extraction applications [6]. An example concerning urban area mapping is provided in Section III-A.

(a)

(b)

Fig. 2: Castel Volturno (Italy): (a) Level-1α product obtained using the band disposition adopted for Fig. 1, and (b) Level-1α product obtained by exchanging the role of the reference image and of the coherence bands. In a temperate environment, this solution allows for obtaining a composition closer to the natural color palette.

B. *Level-1β products*

Level-1β products are obtained by combining a time-series in an unique RGB frame [2]. These products are particularly oriented toward classification applications. In fact, they are composed by temporal features useful to discriminate objects basing on their time dynamics. As for Level-1α imagery, the objective is to provide an image with a consistent rendering of information, in which the association color-feature is stable.

In Fig. 3, a sample Level-1β product is provided. It concerns a subset of the Castel Volturno scene previously discussed. The product is built loading on the red band the time series variance; on the green band the mean intensity; on the blue band a combination of the saturation index (it is proportional to the maximum span in backscattered energy) and of the interferometric coherence. In particular, the coherence is used when its value is above a user-defined threshold, and it is useful to separate the built-up feature from highly variable natural targets.

Fig. 3: Castel Volturno (Italy): Level-1β product composed by six images belonging to the summer season of the year 2010.

As for Level-1α imagery, the colors restituted by the composition have a precise physical explanation. As an example (see Reference 2 for further details):

- The sea surface is rendered in blue due to the Bragg scattering causing a significant contribution of the saturation index;
- Unchanged land cover/grasslands are rendered in green due to the dominance of the mean intensity;
- The built-up feature is rendered in cyan due to the combined contribution of the interferometric coherence and of the mean intensity;
- Growing crops are rendered in yellow or pink due to a significant contribution of the variance and/or of the saturation index, depending on the kind of cultivation and on the harvesting time.

We will discuss an application exploiting these products in Section III-B.

III. Applications

A. Urban area mapping

The block diagram of the proposed algorithm for urban area mapping is shown in Fig. 4. The input product is an RGB image of the Level-1α or Level-1β family. It is treated with self-organizing map (SOM) clustering [7] for dimensionality reduction. As discussed in [2], the use of SOM clustering allows for obtaining a discrete product, with few classes, in which the semantic of the input RGB product is mainly preserved. This way, a coarse urban area map can be easily produced by selecting (automatically or with supervision) the classes most relevant with the urban environment.

OBIA has the purpose to connect sparse objects identified as urban in the coarse map, avoiding an unreliable fragmentation of the retrieved urban area.

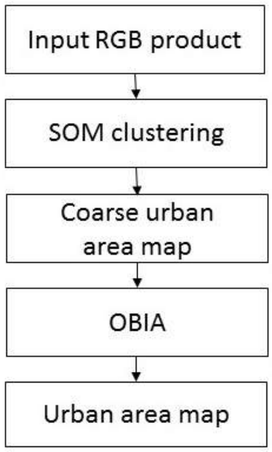


Fig. 4: Block diagram of the proposed workflow for urban area mapping.

In Fig. 5, we show a picture concerning this processing chain. In particular, in Fig. 5a, the input RGB product, depicting an area at North of the city of Napoli (Italy) is shown. The urban area map, obtained running the chain reported in Fig. 4 and re-projected into the relevant Urban Atlas polygons, is shown in Fig. 5b.

The performance of the proposed urban area mapping algorithm has been assessed by comparison with a Urban Atlas-derived ground truth, and satisfying results were obtained. In fact, we found an overall accuracy of about 90% for the considered cases study.

B. Land cover mapping

As stated in Section II-B, Level-1β products can be effectively exploited for supervised/unsupervised classification. In particular, here we suggest the use of Kohonen's self-organizing maps (SOMs) [7] for unsupervised clustering.

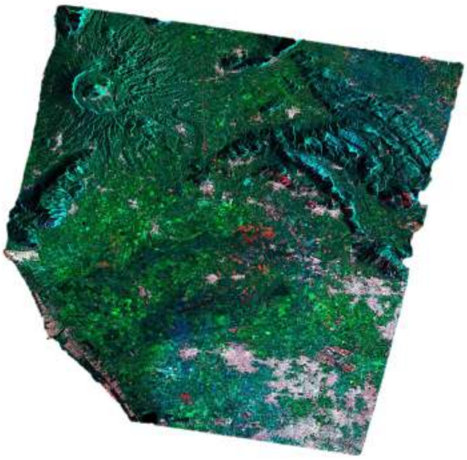
In Fig. 6a, we show the Level-1β product we used as input for this activity. It concerns the city of Dresden, and has been obtained by fusion of six images acquired by the Sentinel-1A satellite between October and December 2014. The product resolution is about 15 meters.

In Fig. 6b, a 5-class land cover map obtained through SOM clustering is shown. The class-object association is the following: cyan-urban area, orange-growing vegetation, dark green-woods, light green-grassland, black-water/weak scatterers.

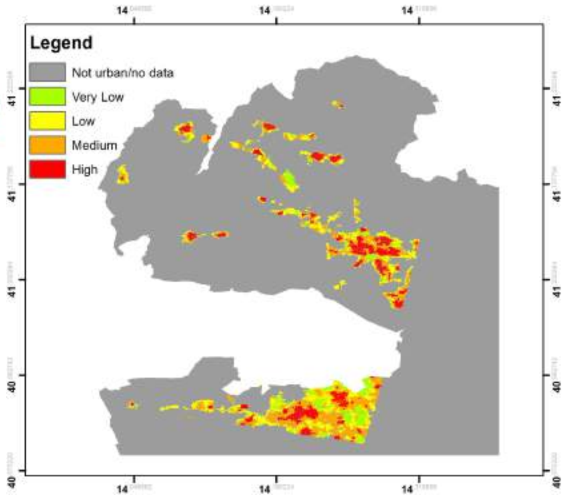
The reader should note that the clustered product looks quite similar to the input RGB product. This is due to the characteristics of the Kohonen's network This way, as detailed in Reference 2, an immediate semantic transferring between the two products is possible.

IV. Conclusions

In this paper, we presented a new framework for RGB composition of multitemporal SAR data. The aim of our processing chain is to provide products enhancing the user experience with data and exploitable in combination with standard algorithms for information extraction.

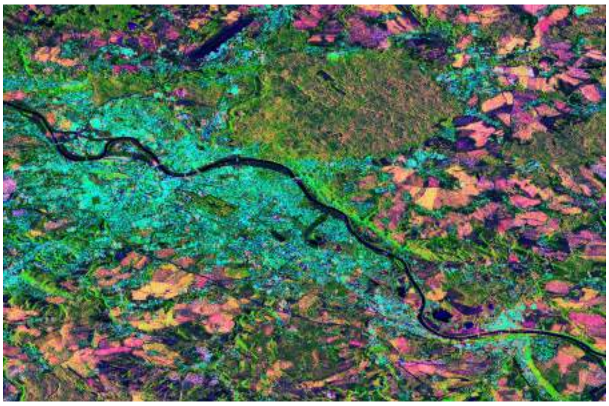


(a)

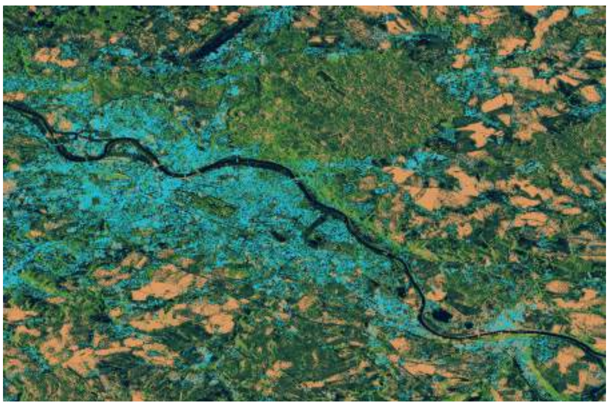


(b)

Fig. 5: Urban area mapping. (a) Input RGB product and (b) final urban area map re-projected into the Urban Atlas grid.



(a)



(b)

Fig. 6: Dresden (Germany): (a) Level-1β product and (b) its 5-class land cover map generated through SOM clustering.

The principal characteristics of the proposed Level-1α and Level-1β products have been demonstrated through examples showing that the rendering is guided by electromagnetic scattering mechanisms. For some features, the rendering is very close to the natural color palette, thus helping user understanding. When the natural color display is not guaranteed, the association color-object, being physical-based, is stable for variation of sensor, scene, and climatic condition.

The suitability of our RGB products with applications has been demonstrated through two examples dealing with urban area and land cover mapping. In both cases, the information was reached through the exploitation of simple, end-user oriented techniques.

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