PRISMA "Super Resolution" Images: Hyperspectral Multispectral Data Fusion with Sentinel-2

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Abstract. *This article addresses the problem of improving the spatial resolution of PRISMA (Hyperspectral Precursor of the Application Mission) Hyperspectral (HS) data, mission with 30-meter ground sampling distance (GSD) To achieve this goal, higher spatial resolution data from the Sentinel-2 (S2) mission are exploited. In particular, ten S2 bands at 10 and 20 m spatial resolution are used to process the PRISMA super-resolution (SR) image. The procedure is applied to real images downloaded from the PRISMA and Copernicus reference portals and then processed by Erdas Imagine software. The first step involves the coregistration of two images to correct georeferencing errors. The second step consists in the fusion between PRISMA and Sentinel-2 data. In the last step, the spectra of some materials are analysed and the Spectral Angles are calculated to assess the effectiveness of the operation performed.*

Keywords. PRISMA, Sentinel-2, hyperspectral (HS), multispectral (MS), super-resolution (SR), coregistration, data fusion

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1 Introduction

The PRISMA (Hyperspectral Precursor of the Application Mission) mission, managed by Italian Space Agency (ASI), is composed of the few satellite missions with a hyperspectral (HS) sensor that acquiring narrow and contiguous images arranged from visible to mid-infrared spectrum (400 to 2500nm) reaching a spectral resolution of 239 bands. PRISMA can provide valuable information to support the prevention of natural risks, such as hydrogeological hazards and anthropogenic risks (including soil pollution), the monitoring of cultural heritage, agricultural activities, up to material mapping or detection operations [1,2,3].

Since its main objective is to provide data at several bands, the HS PRISMA sensor has a limited spatial resolution, 30 m, and this low value can reduce the range of potential applications [4]. The aim of this research is focused on data fusion between an HS and a higher spatial resolution multispectral (MS) image to improve the performance of PRISMA data. This approach is called HS-MS image fusion, or HS super-resolution (SR) [5].

The MS image used for the fusion was acquired from Sentinel-2 (S2) satellite, part of the Copernicus programme managed by the European Commission. In particular, ten S2 bands with a spatial resolution of 10 m (B2-B4, B8) and 20 m (B5-B7, B8a, B11-B12) cover the same spectral range as PRISMA sensor (239 bands).

The software used for the Data Fusion operation is ERDAS IMAGE, produced by Hexagon Geospatial and licensed thanks to the valuable collaboration with Planetek Italia. ERDAS IMAGE is a complete software suite, specifically developed for classification, orthorectification, mosaicing, reprojection and photointerpretation operations.

2 Methods and Results

The images were downloaded from their respective portals. For PRISMA an image of Cagliari area was selected, one of the few images pre-processed with the new encoding algorithm based on GCP - Gran Control Points. This new algorithm allows a geocoding error of less than 15m (compared to the previous one of 200m).

Once the PRISMA image in .he5 format has been imported into the ERDAS software using a special plug-in developed by Planetek, the acquisition date and View Zenith Angle were extracted from the metadata file, information that is fundamental to download a Sentinel-2 image with similar features, in our case the image acquired on March 9, 2022.

The downloaded images were co-registered to correct georeferencing errors. The procedure was carried out within the ERDAS suite via the AutoSync Workstation and the APM (Automatic Point Managment) Strategy command.

In order to achieve the fusion operation between the two images, the sensor bands with common wavelength (nm) values must be identified; the overlap between the nominal spectral response functions (SRFs) of the S2 bands and those of the PRISMA sensor is shown in figure 1.

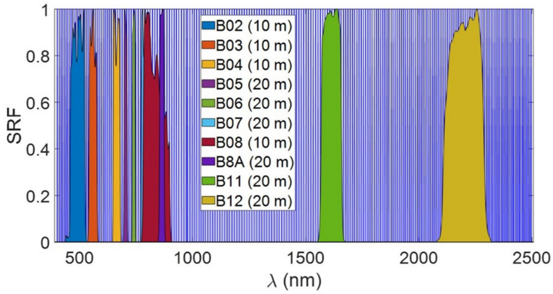

Figure 1. Central wavelengths of the PRISMA bands (blue bars) and SRF of the Sentinel-2 bands

Ten separate images were obtained using the HPF (High Pass Filter) Resolution Merge algorithm, an optimal method for preserving the spectral information of the images. The ten images were superimposed by means of a 'Layer Stack' operation to obtain the super-resolution HS (SR) image (Figure 2).

Figure 2. Left Sentinel-2 image, centre PRISMA image, right HS super resolution (SR) image

In order to investigate the performance of data fusion results, a spectral analysis was conducted using the Spectral Angle value compute on selected materials. The spectral similarity is obtained by considering each spectrum as a vector in q-dimensional space, where q is the number of bands [6].

$$\alpha = cos^{-1}\left[\frac{\sum_{i=1}^{n}(T_i \cdot R_i)}{(\sum_{i=1}^{n} T_i^2)^{\frac{1}{2}} \cdot (\sum_{i=1}^{n} R_i^2)^{\frac{1}{2}}}\right] \quad (1)$$

A set of nine points marked by homogeneous material was examined; the Spectral Angle value between the spectrum of the original PRISMA image and that of the super-resolved HS (SR) image was calculated (Table 1). The results demonstrate good agreement between the two analysed spectra (Figure 3).

Spectral Angle values tend to zero especially in areas characterised by a larger surface area with homogeneity of material present within the area. Therefore, the result obtained can be considered acceptable.

Table 1. Set points, descriptions and values Spectral Angle

ID-Point	Latitude	Longitude	Description	α (Spectral Angle)
1	39°15'13.98"N	9° 3'30.22"E	Airport (tarmac)	0.032
2	39°16'32.21"N	9° 3'2.03"E	Parking area (tarmac)	0.045
3	39°16'58.90"N	9° 3'13.99"E	Farmland (in a rural area)	0.022
4	39°15'28.98"N	9° 3'53.12"E	Industrial shed roofing	0.089
5	39°17'8.62"N	9° 4'26.01"E	Brick-making furnace	0.085
6	39°14'51.55"N	9° 5'55.97"E	Farmland (in an urban area)	0.023
7	39°15'34.68"N	9° 4'22.71"E	Photovoltaic system	0.126
8	39°15'32.28"N	9° 4'56.13"E	Shopping center roofing	0.052
9	39°16'23.61"N	9° 4'3.93"E	Dense vegetation area	0.124

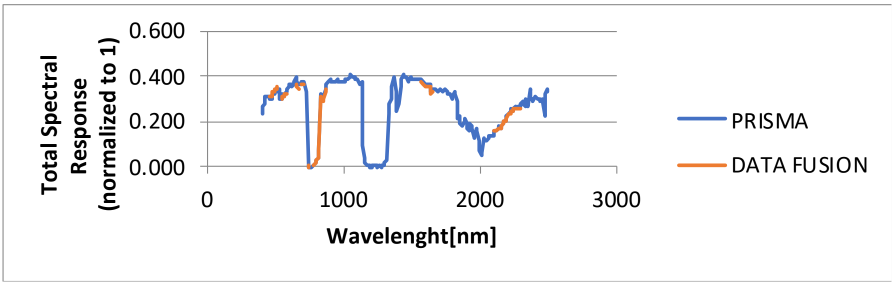

Figure 3. Comparison of spectral signatures: PRISMA and HS-SR image (ID-Point:1)

3 Conclusions

This article presents an end-to-end procedure called PRISMA SR (super-resolution) capable of increasing the spatial resolution of PRISMA HS-HyperSpectral data. The proposed procedure is based on the idea of exploiting the Sentinel-2 data acquired with a spatial resolution of 10 and 20 m to obtain a super-resolved PRISMA image with a pixel size of 10 m. The two images were co-registered to correct georeferencing errors, then the fusion operation was carried out with the HPF (High Pass Filter) Resolution Merge algorithm, indicated in the existing literature as the most effective method for preserving the spectral information of the images. The results were then discussed on the basis of the values of the Spectral Angle, considered as a parameter to measure the similarity between the two PRISMA and PRISMA SR spectra.

The method described encourages future efforts to test new fusion algorithms in order to obtain super-resolved images for Material Mapping or Material Detection by fully exploiting the enormous potential of hyperspectral sensors.

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