The impact of the spatial resolution of highly resolved spectral data on pan-sharpening methods to reconstruct a hyperspectral image

Maxime Ryckewaert, Alexia Gobrecht, Julien Morel, Jean-Michel Roger, Fabienne Henriot, Nathalie Gorretta

The impact of the spatial resolution of highly resolved spectral data on pan-sharpening methods to reconstruct a hyperspectral image.

Ryckewaert Maxime*[12], Gobrecht Alexia[2], Morel Julien[2], Roger Jean-Michel[2] , Henriot Fabienne[1], Gorretta Nathalie[2]

1. *Limagrain Europe, Clermont-Ferrand, France;*

2. *UMR ITAP, IRSTEA, Montpellier, France*

Keywords: Pan-sharpening, precision agriculture, spectrometry, hyperspectral imaging, plant phenotyping

Abstract:

Many precision agriculture applications require acquisition and processing of high spectral and spatial data from remote sensing to capture the subtle differences caused by plant physiological responses and their variability within a crop *(Delalieux et al., 2014)*. This is particularly the case in plant phenotyping.

Even if satellite images are available, their spatial and spectral resolutions are not appropriate for plant phenotyping. Pan-sharpening methods have therefore been developed to increase the spatial resolution of the multispectral information by fusing a panchromatic image (i.e. high spatial /low spectral resolution) with a multispectral one *(Vivone et al., 2015)*. If hyperspectral satellite sensors are about to be available, their spatial resolution is limited *(Loncan et al., 2015; Yokoya et al., 2017)* and the cost of the sensors is still too high for agricultural applications.

In order to overcome the limit of the spatial resolution and to reduce the price of the acquisition, sensors can be used in proximal detection (i.e. at shorter distances to the scene of interest), hand-held or embedded on mobile platforms *(Araus et al., 2015; Deery et al., 2014; Sankaran et al., 2015)*. The objective of this work is to assess the potential of using pan-sharpening methods available in the literature, which are algorithms dedicated to improve the spectral and spatial resolution of multispectral satellite images, on close-range images. And the first issue addressed here is the impact of the spatial resolution of the spectral data on the quality of the reconstructed image.

To do so, a hyperspectral image (from HySpex VNIR 1600) of a sugar beet plot approximately acquired at a height of 1 meter with high-spatial resolution 0.47 mm/pixel and high-spectral resolution (160 bands) in the range of 409 nm – 987 nm has been considered as a reference image. From this reference, a high-spatial resolved panchromatic image is obtained by spectral degradation. On the other hand, the spectral information has been extracted by spatial degradation in a regular grid of NxN pixels giving a spectra number defined by N^2, where N belongs to the interval [2, 20]. The spectrum assigned to the new pixel is the mean of the spectra contained in the reference hyperspectral image.

The fused images are then obtained from different pan-sharpening algorithms organized into three categories : *Component substitution* methods, *Multiresolution analysis* methods and *subspace-based* methods. To assess the quality of the fused image in comparison to the reference image, different figures of merit are computed : a spatial index with the *cross correlation* (CC), a spectral index with the *spectral angle mapper* (SAM) *(Yuhas et al., 1992)* and finally two integrated indices with the *root mean-square error* (RMSE) and the *erreur relative globale adimensionnelle de synthèse* (ERGAS) *(Wald, 2000)*.

From N= 10 (i.e. 100 spectra) where the new pixel size corresponds to 51x51 pixels of the panchromatic image, the values of the quality indices don't greatly improve. For this spatial resolution, the three best methods are *the smoothing filter-based intensity modulation* (SFIM) *(Liu, 2000), Brovey transform* (BT) *(Gillespie et al., 1987)* and the *coupled nonnegative matrix factorization* (CNMF) *(Yokoya et al., 2012)* with respectively 6.65°, 7.49°,

6.07° for the SAM index and 0.794, 0.835, 0.949 for the CC index. For all values of N, the CNMF systematically outperforms the other methods in the spectral and spatial domain confirming the robustness of this method when dealing with hyperspectral data. These promising results are useful to choose the best combination of available cheap sensors.

References

Araus, J.L., Elazab, A., Vergara, O., Cabrera-Bosquet, L., Serret, M.D., Zaman-Allah, M., Cairns, J.E., 2015. New Technologies for Phenotyping, in: Fritsche-Neto, R., Borém, A. (Eds.), Phenomics. Springer International Publishing, Cham, pp. 1–14.

Deery, D., Jimenez-Berni, J., Jones, H., Sirault, X., Furbank, R., 2014. Proximal Remote Sensing Buggies and Potential Applications for Field-Based Phenotyping. Agronomy 4, 349–379. doi:10.3390/agronomy4030349

Delalieux, S., Zarco-Tejada, P.J., Tits, L., Jimenez Bello, M.A., Intrigliolo, D.S., Somers, B., 2014. Unmixing-Based Fusion of Hyperspatial and Hyperspectral Airborne Imagery for Early Detection of Vegetation Stress. IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens. 7, 2571–2582. doi:10.1109/JSTARS.2014.2330352

Gillespie, A.R., Kahle, A.B., Walker, R.E., 1987. Color enhancement of highly correlated images. II. Channel ratio and "chromaticity" transformation techniques. Remote Sens. Environ. 22, 343–365.

Liu, J.G., 2000. Smoothing filter-based intensity modulation: A spectral preserve image fusion technique for improving spatial details. Int. J. Remote Sens. 21, 3461–3472.

Loncan, L., de Almeida, L.B., Bioucas-Dias, J.M., Briottet, X., Chanussot, J., Dobigeon, N., Fabre, S., Liao, W., Licciardi, G.A., Simoes, M., others, 2015. Hyperspectral pansharpening: a review. IEEE Geosci. Remote Sens. Mag. 3, 27–46.

Sankaran, S., Khot, L.R., Espinoza, C.Z., Jarolmasjed, S., Sathuvalli, V.R., Vandemark, G.J., Miklas, P.N., Carter, A.H., Pumphrey, M.O., Knowles, N.R., Pavek, M.J., 2015. Low-altitude, high-resolution aerial imaging systems for row and field crop phenotyping: A review. Eur. J. Agron. 70, 112–123. doi:10.1016/j.eja.2015.07.004

Vivone, G., Alparone, L., Chanussot, J., Dalla Mura, M., Garzelli, A., Licciardi, G.A., Restaino, R., Wald, L., 2015. A Critical Comparison Among Pansharpening Algorithms. IEEE Trans. Geosci. Remote Sens. 53, 2565–2586. doi:10.1109/TGRS.2014.2361734

Wald, L., 2000. Quality of high resolution synthesised images: Is there a simple criterion?, in: Third conference" Fusion of Earth Data: Merging Point Measurements, Raster Maps and Remotely Sensed Images." SEE/URISCA, pp. 99–103.

Yokoya, N., Grohnfeldt, C., Chanussot, J., 2017. Hyperspectral and multispectral data fusion: A comparative review. IEEE Geosci. Remote Sens. Mag. GRSM.

Yokoya, N., Yairi, T., Iwasaki, A., 2012. Coupled nonnegative matrix factorization unmixing for hyperspectral and multispectral data fusion. IEEE Trans. Geosci. Remote Sens. 50, 528–537.

Yuhas, R.H., Goetz, A.F., Boardman, J.W., 1992. Discrimination among semi-arid landscape endmembers using the spectral angle mapper (SAM) algorithm.