Fusing Multispectral and Hyperspectral Images through Pansharpening

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Introduction

- HyperSpectral (HS) sensors are characterized by a very high spectral resolution (i.e., a large number of bands), but their spatial resolution is inadequate for many applications
- If a high spatial resolution PANchromatic (PAN) image is available on the same area they can be combined through data fusion [1, 2]
- Several pansharpening approaches have been proposed for the fusion of multispectral (MS) and PAN image which are acquired by the same satellite [3]

Aim of This Study: Analyze the quality of enhanced HS images by using different classical pansharpening approaches

Pansharpening Algorithms

Pansharpening methods are generally divided into two classes: Component Substitution (CS) and Multi-Resolution Analysis (MRA) techniques [3]

Component Substitution

- Based on a forward transformation of the data, substitution of the PAN image and transformation back in the original space
- The transformation condenses the spatial information common to all the original bands in just one or few components
- The PAN is substituted only to those components retaining the spatial information
- An histogram matching of the PAN image and the components concerned by the substitution is performed
- CS methods obtain fused images with high spatial quality but might be affected by spectral distortions
- The following CS techiques are considered in this work:
  - *Principal Component Analysis* (*PCA*)
  - *Gram Schmidt mode 1* (*GS1*)
  - *Gram Schmidt Adaptive* (*GSA*)

Multi-Resolution Analysis

- Techniques based on the decomposition of each image by iterative applications of a given operator into a sequence of signals (or *pyramid*) with decreasingly informative content
- The spatial details (high frequency signals) are located at the first levels in the decomposition
- Once extracted they are injected in the HS data by additive or multiplicative schemes
- Typically the fusion results of MRA techniques are not very sharp but are more spectrally consistent
- The following MRA techniques are considered in this work:
  - *Smoothing Filter-based Intensity Modulation* (*SFIM*)
  - *Gaussian Laplacian Pyramid* (*GLP-MTF*) with MTF-matched filter
  - *Gaussian MTF-matched filter* with *High Pass modulation* (*MTF-HPM*) injection model

Experimental Results

Hyp+ALI dataset

- HS image acquired by Hyperion 220 spectral bands (from 0.4 to 2.5 μm), 30-meter resolution
- PAN image acquired by ALI with spatial resolution of 10 meters and a spectral coverage form 0.48 μm to 0.69 μm
- Both sensors are mounted on the same platform (no coregistration needed)
- Acquisition over the center of Paris
- In the experiments the sole bands which overlap the spectral range of the panchromatic channel are used (*i.e.*, from band 14 to 33)

CHRIS+QB dataset

- HS image acquired by CHRIS-Proba spatial resolution of 17 meters and 18 bands with a variable spectral resolution, increasing from 1.25 nm at 415 nm to 11.25 nm at 1050 nm (no PAN available!)
- PAN image acquired by QuickBird acquires in the Visible-Near InfraRed spectrum with spatial resolution of 0.6 m
- The size of the PAN image was reduced by using almost ideal low pass filters to obtain a more suitable scale ratio of 4
- Acquisition over the center of Rome

Validation done at full scale with

- D_S index of the Quality without No Reference (*QNR*) for measuring the spatial fidelity
- Spectral Angle Mapper (*SAM*) describing the spectral distortion

Full scale analysis: Quantitative results (optimal values are zero)

Algorithm	SAM(°)	D_S
PCA	0.7928	0.1054
GS1	0.7913	0.1053
GSA	0.8008	0.1062
SFIM	**0.4352**	0.1666
GLP-MTF	0.6650	0.0619
MTF-HPM	0.6554	**0.0593**

Hyp+ALI dataset with perfectly coregistered images

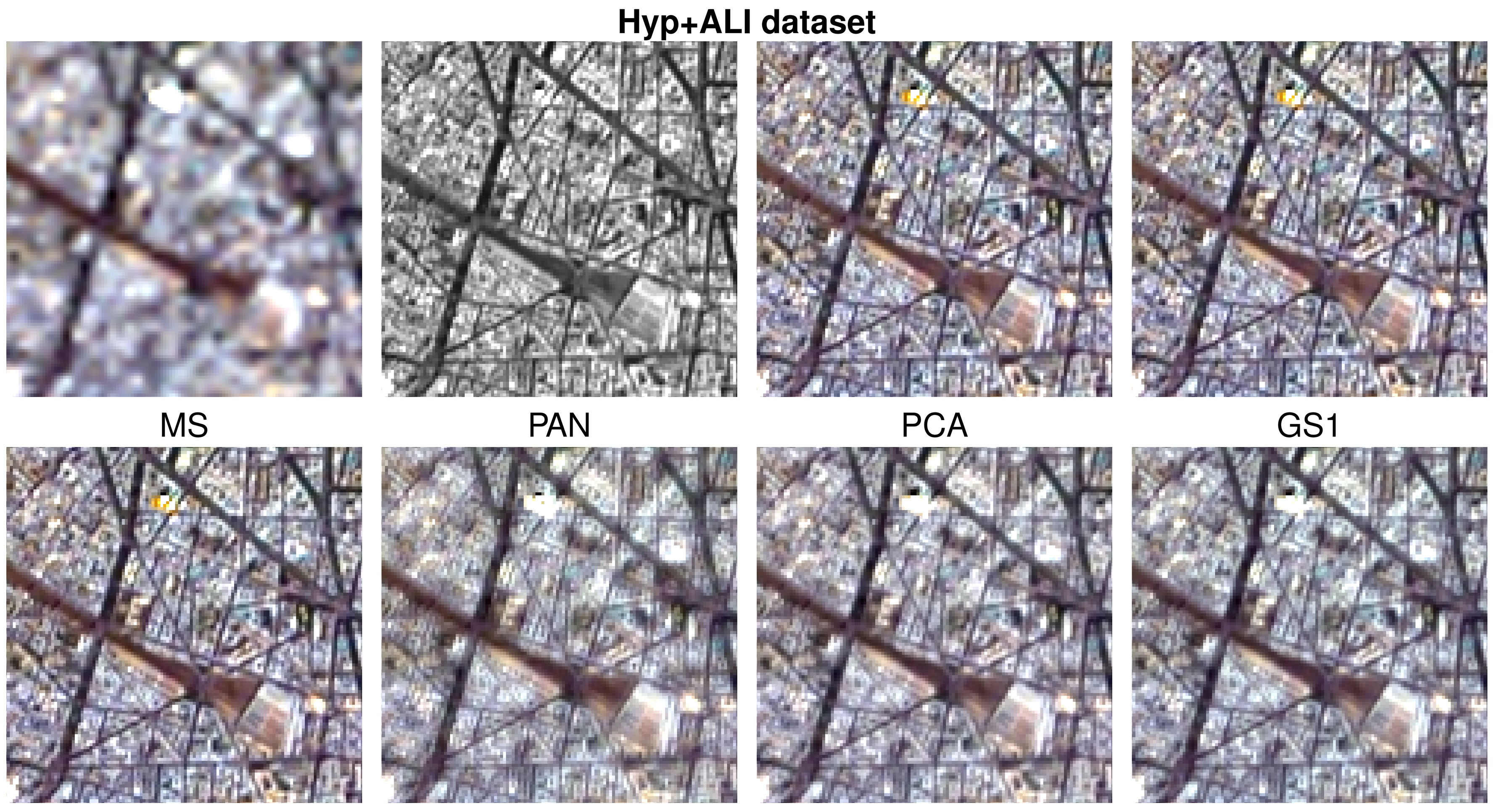
Algorithm	SAM(°)	D_S
PCA	1.3194	0.0597
GS1	1.3159	**0.0595**
GSA	0.8088	0.2525
SFIM	**0.4380**	0.5462
GLP-MTF	0.6895	0.3561
MTF-HPM	0.6590	0.3664

Hyp+ALI dataset with 60 meters misalignment (2 HS pixels)

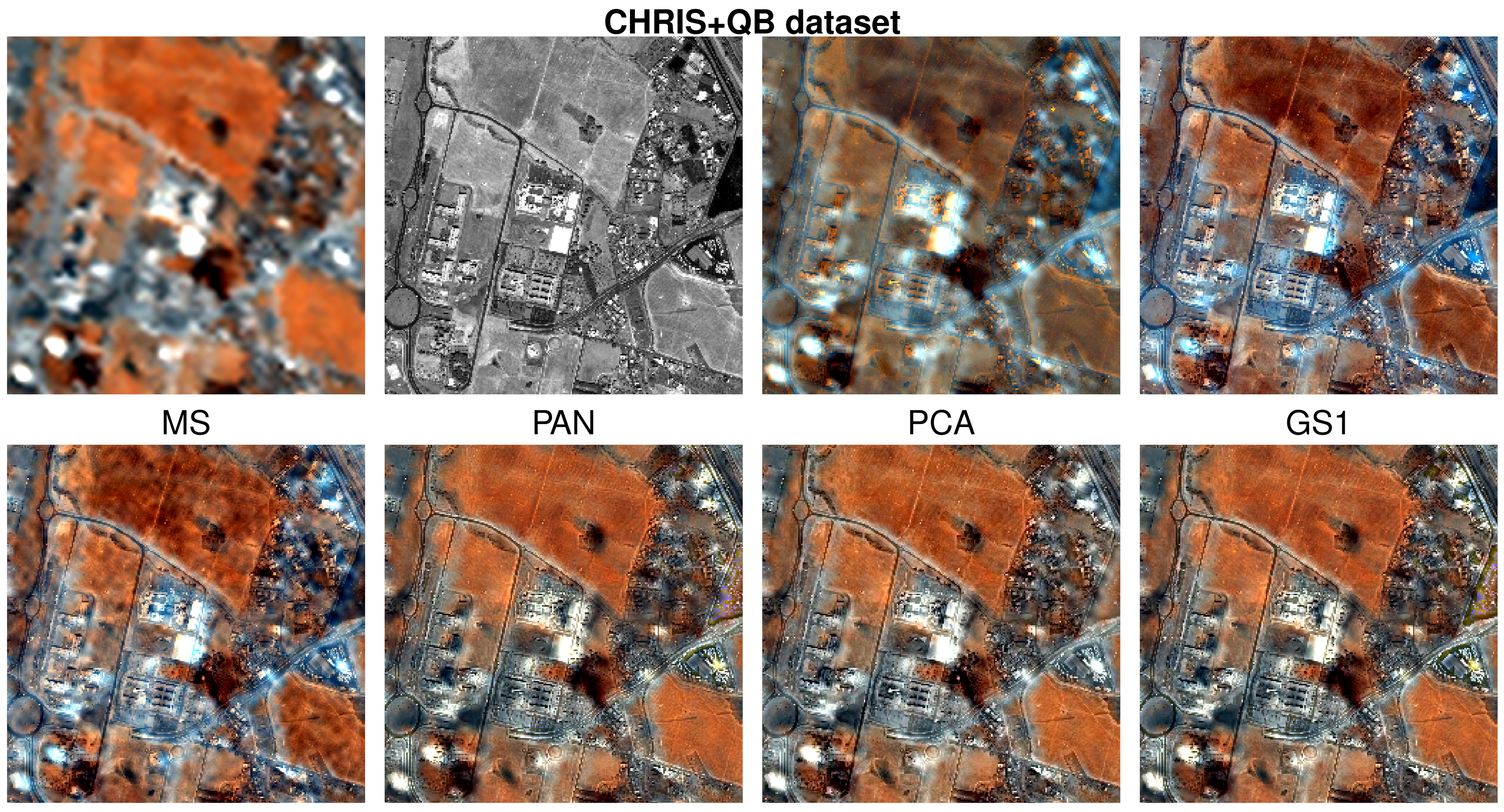
Algorithm	SAM(°)	D_S
PCA	10.6386	**0.2904**
GS1	5.4846	0.4768
GSA	4.9747	0.3866
SFIM	**3.0762**	0.3097
GLP-MTF	4.2274	0.3904
MTF-HPM	3.2355	0.3654

CHRIS+QB dataset with perfectly coregistered images

Hyp+ALI dataset



CHRIS+QB dataset



Discussion and Conclusion

Hyp+ALI dataset

- MRA family: advantages of Gaussian MTF-matched filters with respect to the Box one (used by SFIM)
- the HPM injection model (i.e., multiplicative strategy) shows its superiority with respect to detail addition
- Similar results among the methods in the CS family

CHRIS+QB dataset

- Higher values of *SAM* and D_S w.r.t. Hyp+ALI due to the use of sensors not mounted on the same platform, different fields of view, temporal incoherence
- Slight advantages in performances of CS methods can be evidenced, thanks to the greater robustness to misregistration errors
- Better accuracy for the the Box filter used by SFIM w.r.t. the MTF matched Gaussian due to the preliminary spatial degradation of PAN image

Conclusions

- Superiority of the MRA approaches thanks to the reduction of the spectral distortion, which is very relevant when the number of the band to fuse increases
- CS techniques show a reduced computational burden and the robustness to misregistration errors (see alse the results for a manual shift of the images)

References

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