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# A CRITICAL COMPARISON OF PANSHARPENING ALGORITHMS

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## ABSTRACT

In this paper state-of-the-art and advanced methods for multispectral pansharpening are reviewed and evaluated on two very high resolution datasets acquired by IKONOS-2 (four bands) and WorldView-2 (eight bands). The experimental analysis allows us to highlight the performances of the two main pansharpening approaches (*i.e.* component substitution and multiresolution analysis).

**Index Terms**— Fusion, Pansharpening, Remote Sensing.

## 1. INTRODUCTION

Physical limits of optical imaging devices impose a tradeoff between the achievable spatial and spectral resolutions. This entails that the PANchromatic (PAN) image has no spectral diversity, while a MultiSpectral (MS) image exhibits a lower spatial resolution than the PAN and hence it contains less spatial details. Pansharpening is a data fusion process, whose goal is to enhance the spatial resolution of the MS data by including the spatial details contained in the PAN image.

Most pansharpening methods proposed in the literature follow a general protocol, which is composed by two operations: 1) extract from the PAN image the high-resolution geometrical details of the scene that are not present in the MS image; 2) incorporate such spatial information into the low-resolution MS bands (interpolated to meet the spatial scale of the PAN image) by properly modeling the relationships between the MS bands and the PAN image. This paper aims at providing a critical comparison among classical pansharpening approaches applied to two different datasets. The credited Wald protocol is used for the assessment procedure and some useful guidelines for the comparison are given.

## 2. A CRITICAL REVIEW OF FUSION METHODS

Most recent studies [1] divide the principal image fusion methods into two main classes, according to the way the details are extracted from the PAN image (see Fig. 1). Component Substitution (CS) techniques extract the spatial details by a pixelwise difference between the PAN image and a nonzero-mean component obtained from a spectral transformation of the MS bands, without any spatial filtering of the former. They are referred to as CS methods, since the described process is equivalent to the substitution of such a component with the PAN image followed by reverse transformation to produce the sharpened MS bands [2]. The techniques belonging to the MRA class employ linear space-invariant digital filtering of the PAN image in order to extract the spatial details that will be added to the MS bands [3]. In both cases the injection of spatial details into the interpolated MS bands may be weighed by gains different for each band and possibly varying at each pixel.

## 3. EXPERIMENTAL RESULTS

In this paper we follow the validation protocol for data fusion assessment at reduced scale proposed in [4]. This procedure uses the available MS image as the reference for validating the pansharpening algorithms, which are performed on a spatially degraded version of the original datasets. Despite the questionable assumption of scale invariance, this procedure allows the use of several reliable quality indexes. More in detail we report the values of a classical spectral quality index, the Spectral Angle Mapper (SAM), and two indexes for vector valued images, accounting for both spectral and spatial quality: the  $Q2^n$  [5] and ERGAS [6]. The optimal values are 0 for the SAM and ERGAS and 1 for  $Q2^n$ .

Two datasets of  $300 \times 300$  pixels have been employed. The first (*China dataset*) was acquired over the Sichuan region, China, by IKONOS. This sensor captures four bands



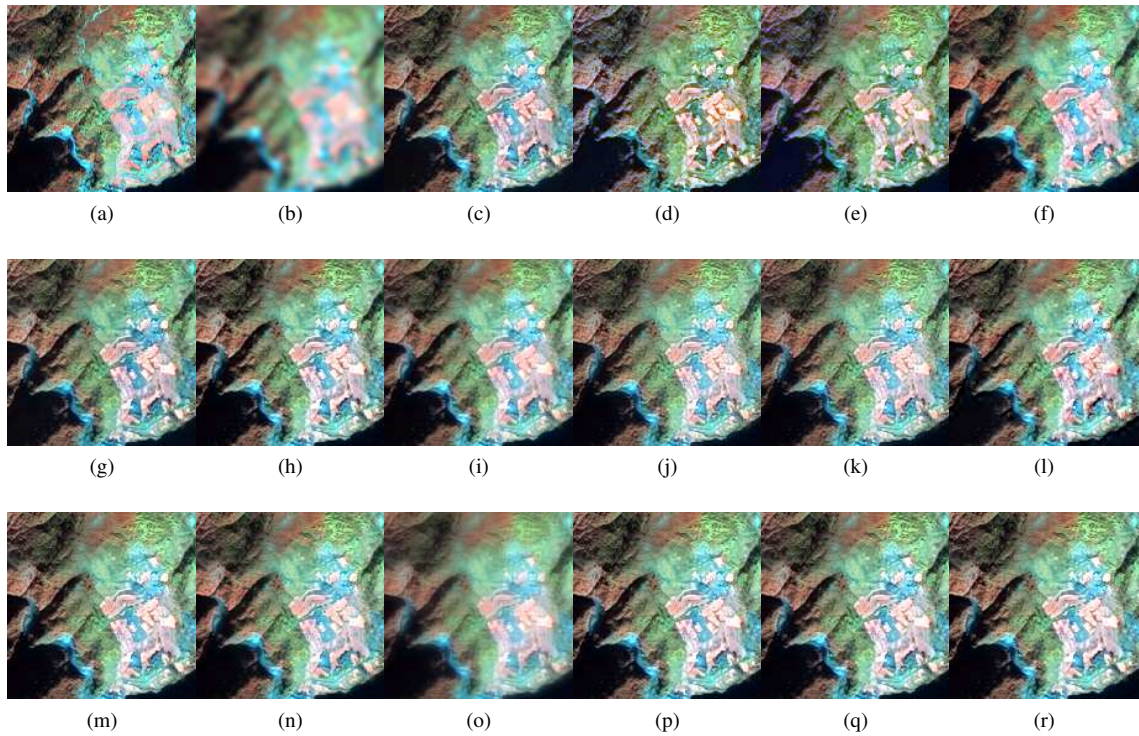
proving the spatial quality (e.g., based on MTF-like filtering) and CS methods in which the combination of bands is aimed at matching the spectral response of the PAN image, thereby preserving the spectral information of the MS original in the pansharpened product (e.g., GSA, BDS, PRACS). Spectral matching, however, becomes critical as the number of bands increases, as shown by the superior performances achieved by MRA on WorldView-2 data.

#### 4. CONCLUSIONS

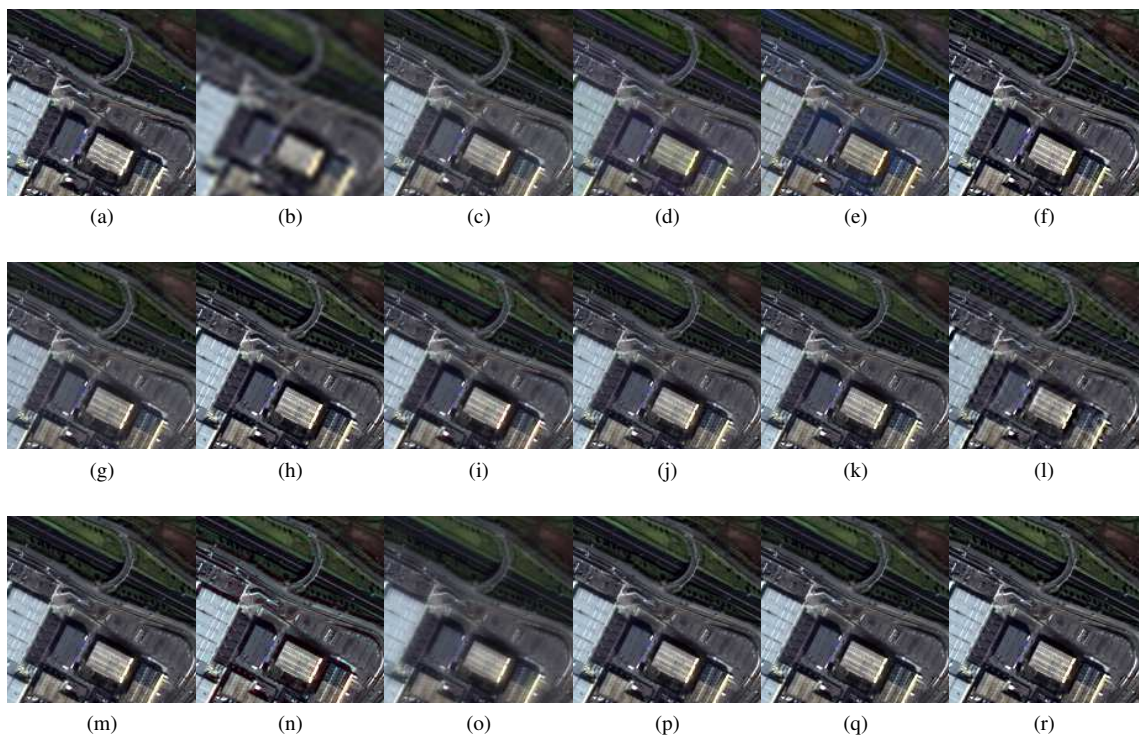
A comparison of several pansharpening methods on two very high resolution datasets has been presented. The validation, performed according to Wald's protocol at reduced scale, highlights the characteristics of the two main classes of methods, based on component substitution and multiresolution analysis, respectively. Future developments shall include the full-scale validation of fusion methods according to the QNR protocol [18] and a more detailed discussion of results.

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**Fig. 2:** China Dataset: (a) Reference Image; (b) EXP; (c) PCA; (d) IHS; (e) Brovey; (f) BDSD; (g) GS; (h) GSA; (i) PRACS; (j) HPF; (k) SFIM; (l) Indusion; (m) ATWT; (n) AWLP; (o) ATWT-M3; (p) MTF-GLP; (q) MTF-GLP-HPM; (r) MTF-GLP-CBD.



**Fig. 3:** Rome Dataset: (a) Reference Image; (b) EXP; (c) PCA; (d) IHS; (e) Brovey; (f) BDSD; (g) GS; (h) GSA; (i) PRACS; (j) HPF; (k) SFIM; (l) Indusion; (m) ATWT; (n) AWLP; (o) ATWT-M3; (p) MTF-GLP; (q) MTF-GLP-HPM; (r) MTF-GLP-CBD.