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IMAGE DEGRADATION FOR QUALITY ASSESSMENT OF PANSHARPENING METHODS

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ABSTRACT: This paper is concentrated on the evaluation of the image fusion techniques applied on the IRS P5 and P6 satellite images. The study area is chosen to cover different terrain morphologies. A good fusion scheme should preserve the spectral characteristics of the source multi-spectral image as well as the high spatial resolution characteristics of the source panchromatic image. In order to find out the fusion algorithm which is best suited for the P5 and P6 images, five fusion algorithms, such as Standard IHS, Modified IHS, PCA, Brovey and wavelet algorithms have been employed and analyzed. In this paper, eight evaluation criteria are also used for quantitative assessment of the fusion performance. The spectral quality of fused images is evaluated by the Spectral discrepancy, Correlation Coefficient (CC), RMSE and Mean Per Pixel Deviation (MPPD). For the spatial quality assessment, the Entropy, Edge detection, High pass filtering and Average Gradient (AG) are applied and the results are analyzed. The analysis indicates that the Modified IHS fusion scheme has the best definition as well as spectral fidelity, and has better performance with regard to the high textural information absorption. Therefore, as the study area is concerned, it is most suited for the IRS-P5 and P6 image fusion.

KEY WORDS: Fusion, IRS, Multisensor, Spatial, Spectral, Evaluation

INTRODUCTION

Due to physical constraint, there is a trade off between spatial resolution and spectral resolution of a high resolution satellite sensor (Aiazzi et al., 2002), i.e., the panchromatic image has a high spatial resolution at the cost of low spectral resolution, and the multispectral image has high spectral resolution with a low spatial resolution (IKONOS: panchromatic image, 1m, multispectral image 4m; QuickBird: panchromatic image, 0.62m, multispectral image, 2.48m). To resolve this dilemma, the fusion of multispectral and panchromatic images, with

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complementary spectral and spatial characteristics, is becoming a promising technique to obtain images with high spatial and spectral resolution simultaneously (Gonzalez-Audicana et al., 2004). Image fusion is widely used to integrate these types of data for full exploitation of these data, because fused images may provide increased interpretation capabilities and more reliable results since data with different characteristics are combined. The images varying in spectral, spatial and temporal resolution may give a more comprehensive view of the observed objects (Pohl and Genderen, 1998).

IMAGE FUSION ALGORITHMS Many methods have been developed in the last few years producing good quality merged images. The existing image fusion techniques can be grouped into four classes:

- color related techniques such as intensity–hue–saturation (IHS) ;
- statistical/numerical methods such as principal components analysis (PCA), high pass filtering (HPF), Brovey transform (BT), regression variable substitution (RVS) methods;
- Pyramid based Methods such as Laplacian Pyramid, Contrast Pyramid, Gradient Pyramid, Morphological Pyramid and Wavelet Methods and
- hybrid methods that use combined methods from more than one group such as IHS and wavelet integrated method.

This study analyzes five current image fusion techniques to assess their performance. The five image fusion methods used include Standard IHS, Modified IHS, PCA, Brovey and wavelet algorithms. IHS (Intensity-Hue-Saturation) is the most common image fusion technique for remote sensing applications and is used in commercial pan-sharpening software. This technique converts a color image from RGB space to the IHS color space. Here the I (intensity) band is replaced by the panchromatic image. Before fusing the images, the multispectral and the panchromatic image are histogram matched. Ideally the fused image would have a higher resolution and sharper edges than the original color image without additional changes to the spectral data. However, because the panchromatic image was not created from the same wavelengths of light as the RGB image, this technique produces a fused image with some color distortion from the original multispectral (Choi et al., 2008). There have been various modifications to the IHS method in an attempt to fix this problem (Choi et al., 2008; Strait et al., 2008; Tu et al., 2004; Siddiqui, 2003). In this research is used modification method suggested by Siddiqui (2003). The Principal Component Analysis (PCA) is a statistical technique that transforms a multivariate dataset of correlated variables into a dataset of new uncorrelated linear combinations of the original variables (Pohl and Genderen, 1998). It is assumed that the first PC image with the highest variance contains the most amount of information from

www.ijsem.org
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the original image and will be the ideal choice to replace the high spatial resolution panchromatic image. All the other multispectral bands are unaltered. An inverse PCA transform is performed on the modified panchromatic and multispectral images to obtain a high-resolution pan-sharpened image. Brovey Transform uses addition, division and multiplication for the fusion of three multispectral bands (ERDAS, 1999). Its basic processing steps are: (1) add three multispectral bands together for a sum image, (2) divide each multispectral band by the sum image, (3) multiply each quotient by a high resolution pan. In wavelet fusion method First, three new panchromatic images are produced according to the histogram of R, G, B bands of multispectral image respectively. Then each of the new highresolution panchromatic images is decomposed into a lowresolution approximation image and three wavelet coefficients, also called detail images, which contain information of local spatial details. The decomposed low-resolution panchromatic images are then replaced by the real low-resolution multispectral image bands (B,G,R), respectively. In the last step, a reverse wavelet transform is applied to each of the sets containing the local spatial details and one of the multispectral bands (B,G,R). After three times of reverse wavelet transforms, the high-resolution spatial details from the panchromatic image are injected into the low-resolution multispectral bands resulting in fused high-resolution multispectral bands (Zhang, 2005)

EXISTING SYSTEM:

Because of signal-to-noise ratio (SNR) constraints and transmission bottleneck, MS images have a good spectral quality but a poor spatial resolution, whereas PAN images have a high spatial resolution but with a coarser/poorer spectral quality. Pan-sharpening is a branch of data fusion used to synthesize MS images at higher spatial resolution than original by exploiting the PAN high spatial resolution, which is important in the field of remote sensing, and many popular mapping products such as Google Maps/Earth use pan-sharpened imagery. Although there is doubt and dispute about the underlying assumption that the synthesis property is consistent among spatial scales, Wald's protocol is still the most widely used protocol today, so it is of the highest priority to validate the assumption of Wald's protocol.

LITERATURE REVIEW

IN "PALSSON, F.; SVEINSSON, J.R.; ULFARSSON, M.O.; BENEDIKTSSON, J.A. MTF-DEBLURRING PREPROCESSING FOR CS AND MRA PANSHARPENING METHODS. IN PROCEEDINGS OF THE INTERNATIONAL GEOSCIENCE AND REMOTE SENSING SYMPOSIUM (IGARSS), MILAN, ITALY, 26–31 JULY 2015; PP. 1104–1107" The fusion of low resolution multispectral (MS) images and high resolution panchromatic (PAN) images, i.e., pansharpening, is an important technique in remote sensing and has many applications where high resolution imagery is important. Component substitution (CS) and multiresolution analysis (MRA) are two large families of pansharpening methods that are fast and computationally efficient. They can be described using a general framework, where details from the PAN image are added to the upsampled and interpolated MS image. However, these methods often suffer from spectral and spatial distortions. We propose a pre-processing step, where instead of just interpolating the MS image to the resolution scale of the PAN image, we do a deconvolution of the interpolated MS image based on the sensor's modulation transfer function (MTF). This results in large improvement gains in the spectral and spatial quality of the fused image. We demonstrate our method using a real WorldView-2 dataset and show that our approach significantly improves the tested methods in both the CS and MRA families of pansharpening methods. Earth imaging satellites such as WorldView-2 (WV2), QuickBird and IKONOS, simultanously acquire MS and PAN images of a scene. Because of cost and complexity factors involved, the MS sensor has a lower spatial resolution than the PAN sensor. In order to make the best use of the acquired data, many methods have been proposed to fuse the two different images, such that the resulting high resolution MS image has both the spectral resolution of the MS image and the high spatial resolution of the PAN image. Today, pansharpening is an important technique in the field of remote sensing and many popular mapping products such as Google Maps/Earth use pansharpened imagery. There are also many applications in remote sensing that rely on high resolution data that benefit from the added resolution, such as classification. Pansharpening methods are based on many diverse techniques. However, one can readily identify two large families of such methods. These are the CS and MRA methods which share a common framework. These are usually simple and fast methods, i.e., practical, that often give good visual results, but often suffer from spectral and spatial distortions. In [1], the authors perform a comparison study between 19 methods from the CS and MRA families and describe the universally accepted evaluation protocols for pansharpened imagery. Another important category of methods are model based methods. They are typically based on an observational model for pansharpening, which is an under-determined inverse problem, whose solution often requires some kind of regularization. Examples of recent model based methods are e.g., [2], [3] and [4]. Recently, there have also been proposed methods based on compressed sensing [5] and sparse representations [6]. These methods are more complex than the CS and MRA methods and are usually iterative in nature, which makes them more computationally costly. One advantage of using a model based method is the incorporation of a data-fidelity term in the cost-function. This stems from the assumption that the observed MS image is a blurred or degraded version of the higher resolution MS image we want to estimate. This introduces a term in the resulting iterative algorithm that performs deconvolution based on the blurring operator assumed in the model. By modeling this operator based on the sensor's MTF, the algorithm performs MTF-deblurring on the MS image. This is one of the most important properties that makes model based methods superior to the CS and MRA methods. The novelty of the proposed approach presented in this paper, is to introduce a pre-processing step to the CS and MRA methods that performs MTF-deblurring on the interpolated MS image. This results in significant increases in quality, both according to well-established quantitative quality metrics and also visual inspection. As an example for our method we use a real WorldView-2 (WV2) MS and PAN images of a rural area in Iceland. The MS image has 8 spectral bands, of which 2 do not overlap with the PAN band. The paper is organized as follows. In Section II, we give a brief overview of the CS and MRA methods. In Section III, we outline the proposed method and in Section IV, we give examples using a real WV2 dataset, at both reduced and full scale. Finally, conclusions are drawn in Section V. In the remainder of this paper we will use the following notation. The observed MS and PAN images are denoted as YMS and YPAN, respectively, and the fused image we desire is denoted by X.

IN "THOMAS, C.; RANCHIN, T.;WALD, L.; CHANUSSOT, J. SYNTHESIS OF MULTISPECTRAL IMAGES TO HIGH SPATIAL RESOLUTION: A CRITICAL REVIEW OF FUSION METHODS BASED ON REMOTE SENSING PHYSICS. IEEE TRANS. GEOSCI. REMOTE SENS. 2008, 46, 1301–1312" Our framework is the synthesis of multispectral images (MS) at higher spatial resolution, which should be as close as possible to those that would have been acquired by the corresponding sensors if they had this high resolution. This synthesis is performed with the help of a high spatial but low spectral resolution image: the panchromatic (Pan) image. The fusion of the Pan and MS images is classically referred as pan-sharpening. A fused product reaches good quality only if the characteristics and differences between input images are taken into account. Dissimilarities existing between these two data sets originate from two causes—different times and different spectral bands of acquisition. Remote sensing physics should be carefully considered while designing the fusion process. Because of the complexity of physics and the large number of unknowns, authors are led to make assumptions to drive their development. Weaknesses and strengths of each reported method are raised and confronted to these physical constraints. The conclusion of this critical survey of literature is that the choice in the assumptions for the development of a method is crucial, with the risk to drastically weaken fusion performance. It is also shown that the Amélioration de la Résolution Spatiale par Injection de Structures concept prevents from introducing spectral distortion into fused products and offers a reliable framework for further developments.

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT
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ALL IMAGING applications that require analysis of two or more images of a scene can benefit from image fusion. We rely on two definitions extracted from literature—Wald's [1] and Piella's [2] definitions, respectively. Wald [1] defines image fusion as "a formal framework in which are expressed means and tools for the alliance of data originating from different sources. It aims at obtaining information of a greater quality, although the exact definition of 'greater quality' will depend on the application". According to Piella [2], fusion is "the combination of pertinent (or salient) information in order to synthesize an image more informative and more suitable for visual perception or computer processing," where the "pertinence" of the information is also dependent on the application task Each application field of image fusion leads to an interpretation of these definitions and also involves specific physical considerations. In this paper, we focus on a particular application field of image fusion in remote sensing, which is the synthesis of multispectral (MS) images to the higher spatial resolution of the panchromatic (Pan) image. The main spectral characteristic of the Pan modality is to cover a broad range of the wavelength spectrum, whereas an MS band covers only a narrow spectral range. Since more energy comes to Pan sensor, time acquisition can be reduced still preserving the same intensity response as MS images in terms of the number of photons. The advantage of the Pan image is a smaller size of pixels and, hence, better spatial resolution. The Pan image, thus, combines low spectral resolution and high spatial resolution, whereas the MS image combines reverse characteristics. The design of MS sensors with better resolution is limited by technical constraints of onboard storage and bandwidth transmission of the images from the satellite to the ground. Therefore, due to a combination of observational constraints imposed by the acquisition system, spaceborne imagery usually provides separated but complementary product types. An increasing number of applications such as feature detection [3] or land cover classification [4] require high spatial and high spectral resolution at the same time for improved classification results, strengthened reliability, and/or a better visual interpretation. In response to those requirements, image fusion has become a powerful solution to provide an image containing the spectral content of the original MS images with enhanced spatial resolution. This particular field of application of data fusion is usually called pan-sharpening. More precisely, the framework of the presented study is the synthesis of fused MS images that should be as close as possible to those that would have been observed if the corresponding sensors had this high spatial resolution. Even with geometrically registered Pan and MS images, dissimilarities might exist between these modalities. In addition to changes produced by their different spectral acquisition bands of Pan and MS images, drastic changes might also occur in the scene for two different acquisition times. Many authors attempt to figure out relationships between these remotely sensed images for the development of their fusion method. However, because of variations between these images, no obvious universal link exists. This is the emphasis of this paper, which demonstrates that physics must be taken into account and discusses ways to do so. The reliability of the starting assumption adopted by several publications is discussed and confronted to physics. The purpose of this critical survey is to highlight the domain of validity and the shortcomings of such approaches compared to others, leading to recommendations for adopting existing methods or developing new ones.

IN "WANG, Z.; ZIOU, D.; ARMENAKIS, C.; LI, D.; LI, Q. A COMPARATIVE ANALYSIS OF IMAGE FUSION METHODS. IEEE TRANS. GEOSCI. REMOTE SENS. 2005, 43, 1391–1402." There are many image fusion methods that can be used to produce high-resolution mutlispectral images from a high-resolution panchromatic image and low-resolution mutlispectral images. Starting from the physical principle of image formation, this paper presents a comprehensive framework, the general image fusion (GIF) method, which makes it possible to categorize, compare, and evaluate the existing image fusion methods. Using the GIF method, it is shown that the pixel values of the high-resolution mutlispectral images are determined by the corresponding pixel values of the low-resolution panchromatic image, the approximation of the high-resolution panchromatic image at the low-resolution level. Many of the existing image fusion methods, including, but not limited to, intensity–hue–saturation, Brovey transform, principal component analysis, high-pass filtering, high-pass modulation, the à trous algorithm-based wavelet transform, and multiresolution analysis-based intensity modulation (MRAIM), are evaluated and found to be particular cases of the GIF method. The performance of each image fusion method is theoretically analyzed based on how the corresponding low-resolution panchromatic image is computed and how the modulation coefficients are set. An experiment based on IKONOS images shows that there is consistency between the theoretical analysis and the experimental results and that the MRAIM method synthesizes the images closest to those the corresponding multisensors would observe at the high-resolution level T HE CONCEPT of data fusion goes back to the 1950's and 1960's, with the search for practical methods of merging images from various sensors to provide a composite image which could be used to better identify natural and manmade objects. Terms such as merging, combination, synergy, integration, and several others that express more or less the same concept have since appeared in the literature. In the remote sensing community, the following definition has been adopted: "Data fusion is a formal framework in which are expressed means and tools for the alliance of data originating from different sources. It aims at obtaining information of greater quality; the exact definition of 'greater quality' will depend upon the application" In optical remote sensing, with physical and technological constraints, some satellite sensors supply the spectral bands needed to distinguish features spectrally but not spatially, while other satellite sensors supply the spatial resolution for distinguishing features spatially but not spectrally. For many applications, the combination of data from multiple sensors provides more comprehensive information. Several commercial earth observation satellites carry dual-resolution sensors of this kind, which provide high-resolution panchromatic images (HRPIs) and low-resolution multispectral images (LRMIs). For example, the first commercial high-resolution satellite, IKONOS, launched on September 24, 1999, produces 1-m HRPIs and 4-m LRMIs. This permits identification of objects approximately one meter in length (even less in some cases) on the earth's surface, using a satellite in outer space. It is particularly useful in urban areas because the characteristics of urban objects are determined not only by their spectra but also by their structure. It is therefore necessary and very useful to fuse HRPIs and LRMIs. Many image fusion methods have been proposed for combining an HRPI with LRMIs. A detailed review on this issue was given by Pohl and Van Genderen [2]. Some methods, such as intensity–hue–saturation (IHS) [3]–[8], Brovey transform (BT) [9], [10], and principal component analysis (PCA) [10], [11], provide superior visual high-resolution multispectral images (HRMIs) but ignore the requirement of high-quality synthesis of spectral information. While these methods are useful for visual interpretation, high-quality synthesis of spectral information is very important for most remote sensing applications based on spectral signatures, such as lithology and soil and vegetation analysis [7]. Garguet-Duport et al. [12] has shown that the high-quality synthesis of spectral information is particularly well suited in the case of vegetation analysis. Wald et al. [13] suggests that the fused HRMIs should be as identical as possible to the real HRMIs the corresponding multispectral sensors would observe at the high-resolution level. A large amount of research has been done in terms of this constraint. The high-pass filtering (HPF) [14]–[18] and high-pass modulation (HPM) [16] methods and those of [19] and [20] have shown better performance in terms of the high-quality synthesis of spectral information. More recently, an underlying multiresolution analysis employing the discrete wavelet transform has been used in image fusion. It was found that multisensor image fusion is a tradeoff between the spectral information from an LRMI sensor and the spatial information from an HRPI sensor. With the wavelet transform fusion method, it is easy to control this tradeoff [10]. Currently used wavelet-based image fusion methods are mostly based on two computation algorithms: the Mallat algorithm [10], [18], [21]–[24] and the à trous algorithm [18], [25]–[28]. The Mallat algorithm-based dyadic wavelet transform (WT), which uses decimation, is not

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shift-invariant and exhibits artifacts due to aliasing in the fused image [18], [26]. In contrast, the à trous algorithm-based dyadic wavelet transform (ATW) method, which does not use decimation, is shift-invariant, a characteristic that makes it particularly suitable for image fusion. Note that these methods are well suited to cases of image fusion where the resolution ratio between the LRMI and the HRPI is a power of two, although they are also used for ratios that are not powers of two, such as the fusion between the Systeme Pour l' Observation de la Terre (SPOT) panchromatic and Landsat Thematic Mapper multispectral bands [23]. However, some new methods have been proposed to deal better with cases whose ratios are not powers of two. Blanc et al. [29] used the ARSIS concept with iterated rational filter banks, and Shi et al. [30] used the Mallat algorithm and the -band WT for the fusion of SPOT panchromatic and Landsat Thematic Mapper multispectral bands. Moreover, Wang [31] used the multiresolution analysis-based intensity modulation (MRAIM) method based on the à trous algorithm and the -band WT (the main strategy behind this approach will be introduced in a later section), and Aiazzi et al. [18] extended the Laplacian pyramid (LP) to the generalized LP (GLP) method to deal with cases whose ratios are arbitrary integers. The existing image fusion methods can be classified into several groups. Schowengerdt [16] classified them into spectral domain techniques, spatial domain techniques, and scale space techniques. Ranchin and Wald [24] classified them into three groups: projection and substitution methods, relative spectral contribution methods, and those relevant to the ARSIS concept. It was found that many of the existing image fusion methods, such as the HPF, WT, and ATW methods, can be accommodated within the ARSIS concept. Tu et al. [8] also performed a mathematical evaluation and found that the PCA, BT, and ATW methods can be accommodated as IHS-like image fusion methods. In this vein, the main objective of this paper is to propose a comprehensive framework, the general image fusion (GIF) method, which makes it possible to categorize, compare, and evaluate the existing image fusion methods

IN "AMRO, I.; MATEOS, J.; VEGA, M.; MOLINA, R.; KATSAGGELOS, A.K. A SURVEY OF CLASSICAL METHODS AND NEW TRENDS IN PANSHARPENING OF MULTISPECTRAL IMAGES. EURASIP J. ADV. SIGNAL PROCESS. 2011, 2011, 1–22." There exist a number of satellites on different earth observation platforms, which provide multispectral images together with a panchromatic image, that is, an image containing reflectance data representative of a wide range of bands and wavelengths. Pansharpening, is a pixel level fusion technique used to increase the spatial resolution of the multispectral image while simultaneously preserving its spectral information. In this paper we provide a review of the pansharpening methods proposed in the literature giving a clear classification of them

www.ijsem.org
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Vol 14, Issuse.3 july 2023

and a description of their main characteristics. Finally we analyze how the quality of the pansharpened images can be assessed both visually and quantitatively and examine the different quality measures proposed for that purpose. Nowadays, huge quantities of satellite images are available from many earth observation platforms, such as SPOT [1], Landsat 7 [2], IKONOS [3], QuickBird [4] and OrbView [5]. Moreover, due to the growing number of satellite sensors, the acquisition frequency of the same scene is continuously increasing. Remote sensing images are recorded in digital form and then processed by computers to produce image products useful for a wide range of applications. The spatial resolution of a remote sensing imaging system is expressed as the area of the ground captured by one pixel and affects the reproduction of details within the scene. As the pixel size is reduced, more scene details are preserved in the digital representation [6]. The instantaneous field of view (IFOV) is the ground area sensed at a given instant of time. The spatial resolution depends on the IFOV. For a given number of pixels, the finer the IFOV is, the higher the spatial resolution. Spatial resolution is also viewed as the clarity of the high frequency detail information available in an image. Spatial resolution in remote sensing is usually expressed in meters or feet, which represents the length of the side of the area covered by a pixel. Figure 1 shows three images of the same ground area but with different spatial resolutions. The image at 5m depicted in Fig. 1a was captured by the SPOT 5 satellite while the other two images, at 10m and 20m, are simulated from the first image. As can be observed in these images, the detail information becomes clearer as the spatial resolution increases from 20m to 5m. Spectral resolution is the electromagnetic bandwidth of the signals captured by the sensor producing a given image. The narrower the spectral bandwidth is, the higher the spectral resolution. If the platform captures images with a few spectral bands, typically 4 to 7, they are referred to as multispectral (MS) data, while if the number of spectral bands is measured in hundreds or thousands, they are referred to as hyperspectral (HS) data [7]. Together with the MS or HS image, satellites usually provide a panchromatic (PAN) image. This is an image that contains reflectance data representative of a wide range of wavelengths from the visible to the thermal infrared, that is, it integrates the chromatic information therefore the name is “pan” chromatic. A PAN image of the visible bands captures a combination of red, green and blue data into a single measure of reflectance. Remote sensing systems are designed within often competing constraints, among the most important ones being the trade-off between IFOV and signal-to-noise ratio (SNR). Since MS, and to a greater extent HS, sensors have reduced spectral bandwidths compared to PAN sensors, they typically have for a given IFOV a reduced spatial resolution in order to collect more photons and preserve the image SNR. Many sensors such as SPOT, ETM+, IKONOS, OrbView, and QuickBird have a set of MS bands and a co-registered higher spatial resolution PAN band. With appropriate algorithms it is possible to combine these data and produce MS imagery with higher spatial resolution. This concept is known as multispectral or multisensor merging, fusion, or pansharpening (of the lower-resolution image) [8]. Pansharpening, can consequently be defined as a pixel level fusion technique used to increase the spatial resolution of the MS image [9]. Pansharpening is shorthand for Panchromatic Sharpening, meaning the use of a PAN (single band) image to sharpen an MS image. In this sense, to sharpen means to increase the spatial resolution of an MS image. Thus, pansharpening techniques increase the spatial resolution while simultaneously preserving the spectral information in the MS image, giving the best of the two worlds: high spectral resolution and high spatial resolution [7]. Some of the applications of pansharpening include improving geometric correction, enhancing certain features not visible in either of the single data alone, change detection using temporal data sets, and enhancing classification [10]. During the past years an enormous amount of pansharpening techniques have been developed and, in order to choose the one that better serves to the user needs, there are some points, mentioned by Pohl [9], that have to be considered. In the first place, the objective or application of the pansharpened image can help in defining the necessary spectral and spatial resolution. For instance, some users may require frequent, repetitive coverage, with relatively low spatial resolution (i.e. meteorology applications), others may desire the highest possible spatial resolution (i.e. mapping), while other users may need both high spatial resolution and frequent coverage, plus rapid image delivery (i.e. military surveillance). Then, the data which are more useful to meet the needs of the pansharpening applications, like the sensor, the satellite coverage, atmospheric constraints such as cloud cover, sun angle, etc. have to be selected. We are mostly interested in sensors that can capture simultaneously a PAN channel with high spatial resolution and some MS channels with high spectral resolution like SPOT 5, Landsat 7 and QuickBird satellites. In some cases, PAN and MS images captured by different satellites sensors at different dates for the same scene can be used for some applications [10], like in the case of fusing different MS SPOT 5 images captured at different times with one PAN IKONOS image [11], which can be considered as a multi-sensor, multi-temporal and multi-resolution pansharpening case. We also have to take into account the need for data pre-processing, like registration, up-sampling and histogram matching, as well as, the selection of a pansharpening technique that makes the combination of the data most successful. Finally, evaluation criteria are needed to specify which is the most successful pansharpening approach. In this paper we examine the classical and state-of-the-art pansharpening methods described in the literature giving a clear classification of the methods and a description of their main characteristics. To the best of our knowledge there is no recent paper providing a complete overview of the different pansharpening methods. However, some papers partially address the classification of pansharpening methods, see [12] for instance, or relate already proposed techniques of more global paradigms [13–15].

PROPOSED SYSTEM:

The image sequence constructed following Aiazzi's method illustrates a remarkable dependence from the spatial scale, decreasing with the spatial scale. Meanwhile, the sequence of the proposed method illustrates much less dependency on spatial scale. For all pan-sharpening algorithms, the proposed degradation method scored higher than Aiazzi's method at any scale. Particularly, the difference at scale 2 is of most interest because that is the scale where quality assessment is usually taken.

An interesting observation is that adaptive pan-sharpening methods such as BDSD, GSA, MTF-GLP-CBD show minimum dependence on scale. As so-called adaptive algorithms should theoretically perform consistently over scales or landscape patterns, this observation validated the proposed spatial degradation method and these adaptive pan-sharpening algorithms simultaneously.

Advantage:

Pioneering pan-sharpening algorithms focused on visual enhancement and quantitative quality validation issues were at an early stage, while the guideline of second generation techniques is to meet the requirement of high-quality synthesis of spectral information because it is very important for most remote sensing applications based on spectral signatures. That makes the quality assessment of pan-sharpened MS images a fundamental task. However, it is still a much debated topic.

Another problem is that the decimation process is not carefully handled, which might lead to a shift of images. Although zero-phase filter and standard decimation would not introduce shift to digital signals, the situation is a little different in remotely sensed image processing. The difference is that element of an image is not measurement at a point but integral of measurement over an area.

Disadvantage:

Because of signal-to-noise ratio (SNR) constraints and transmission bottleneck, MS images have a good spectral quality but a poor spatial resolution, whereas PAN images have a high spatial resolution but with a coarser/poorer spectral quality.

Pan-sharpening is a branch of data fusion used to synthesize MS images at higher spatial resolution than original by exploiting the PAN high spatial resolution, which is important in the field of remote sensing, and many popular mapping products such as Google Maps/Earth use pan-sharpened imagery.

CONCLUSION

As Aiazzi's method would introduce inconsistency among scales, as Figure 1 implies, this paper proposed an improved spatial degradation method forWald's protocol. Simulation shows that when images are spatially degraded by MSD4FV, the performance of pan-sharpening algorithms manifest weak dependence on spatial scale, which supports the hypothesis assumed by Wald's protocol. In particular, the SCC quality index illustrates the least dependence; however, the difference among pan-sharpening algorithms is also the least, which means that SCC might not be good to discriminate. There is no linear trend for ERGAS that could be observed for SCC and Q2n, and most algorithms reach their peaks at scale of 4 or 5. A possible explanation is that such scales are related to the size of buildings and roads, thus the ERGAS is more sensitive to landscape than Q2n and SCC, which needs more investigation. Although Q2n is monotonically decreasing with scale for either method, MSD4FV yields a much narrower range. So, Q2n is the most suitable single measurement for quality assessment among the tested indices. An interesting observation is that adaptive pan-sharpening methods such as BDSD, GSA, MTF-GLP-CBD show minimum dependence on scale. As so-called adaptive algorithms should theoretically perform consistently over scales or landscape patterns, this observation validated the proposed spatial degradation method and these adaptive pan-sharpening algorithms simultaneously. This paper is a preliminary work, and there are still many open points. First of all, more data sets with different sensors over different landscapes must be tested, and more quality indices should be considered. How the accuracy of nominal MTF would influence quality assessment should be studied, which might lead to the question of how to validate pan-sharpening when MTF is unavailable or inaccurate. Techniques used by adaptive methods mentioned in the letter, along with others handling information among scales such as SIFT [23] and Kalman Filter [24,25], might help in the study. Consistency property measurement is another crucial problem concerning spatial degradation. Study on how the degradation method influence scores of quality indices for a given fusion algorithm would help us understand image fusion more deeply. Finally, the proposed degradation method is actually a new method to extract spatial details, so most MRA-based pan-sharpening algorithms would benefit from the idea of MSD4FV.

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