Preprocessing of Hyperspectral Images for Precision Agriculture

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Abstract— Precision agriculture requires high spectral and spatial resolution imagery for advanced analyses of crop and soil conditions to increase crop yield. Imagery from traditional satellite systems, such as the U.S. Landsat satellites and the French SPOT satellites, has long been used to monitor crop growing conditions and to estimate crop yields over large geographic areas. Hyperspectral images are the images captured in large continuous narrow wavebands provides significant advancement in understanding the subtle changes in biochemical and biophysical attributes of the crop plants and their different physiological processes. Hyperspectral images captured in various narrow bands individually contain complementary information. Fusion of hyperspectral images using hierarchical model is proposed in the work which provides a single image containing all complementary information in a single image. Hyperspectral images have been preprocessed for atmospheric correction, radiometric correction and noise removal. Noise removal is carried out in multiresolution framework by applying Bayes thresholding at detail coefficients. Approximate coefficients are also filtered using NLM filter.

Key words: Hyperspectral Images, Precision Agriculture

I. Introduction

The conventional remote sensing satellites collect data on earth objects in the range of few broad wavelengths while the hyperspectral remote sensors record data in the range of hundreds of adjacency located wavelengths, providing ample vistas to examine earth objects in a wide variety of spectral bands, thereby enhancing the quality and details that can be interpreted from remotely sensed data. These hyperspectral data measure the earth objects in a continuous spectrum of each image cell and hence hyperspectral images contain a wealth data, but interpreting them is often complex process that requires a thorough understanding of physiochemical properties of ground materials. The need for a crop sensor for monitoring input resource application: especially nitrogen in field crops has been realized since the earliest days of computer controlled precision agriculture in the 1980s. However, most of the commercial precision agriculture has been mostly based on maps with specific requirement of highly skilled personnel. Besides, such an approach is time consuming and often the required input reaches farmer much later than when required. Therefore, the use of real-time sensing through ground based remote sensors and their integration with satellite remote sensing may help to reduce the time gap with applicability in much larger area. In addition, this may also be helpful in developing variable rate input application technology for site-specific crop management. Such innovative crop management may be used to integrate both preventive and field specific strategies to increase the profitability various weeds in terms of tonnage and quality through enhanced resource use efficiency particularly in this on duration crop being cultivated throughout the country both in tropics and sub-tropics under diverse agro climatic conditions. Identification of Vegetation species and to detect vegetation stress hyperspectral imagery has been used. Over the past decade hyperspectral imagery also helped in measurement of plant physiology such as leaf area index, water content, plant pigment content, canopy architecture [1]-[6].

II. Methodology

A. *Fusion of Hyperspectral Images*

Hyperspectral In the proposed fusion method we compute weight that depends on the local structures in the image. Each pixel in the fused image corresponds to the normalized weighted average at the corresponding locations. To make the weight as a function of local structures in the image, smoothed image is subtracted from the original image. Thus, weak edges and fine structures are separated. Inspired by the work proposed in [7] for compositing of low-dynamic-intensity photographs, we propose to fuse remote sensing images with variable reflectance. Properties of hyperspectral images are quite different when compared to HDR images. By incorporating bilateral kernel, both regional and structural information can be included in the computation of patch similarity which help in enhancing edge preservation. We replace Gaussian kernel Ga(k) of NLM in the Equation 2.1 with the bilateral Gaussian (wG) and range (wR) kernels as

$$G_a(k) = w_G.w_R = e^{-\frac{(m^2+n^2)}{\rho^2}}.e^{-\frac{|v(i,j)-v(i+m,j+n)|^2}{h'^2}} \quad (2.1)$$

We modify the original NLM filter with the newly computed kernel value. Let us define new NLM filter as BNF (Bilateral nonlocal means filter). Let there be L images in the multiband. We define the weight as the difference image as shown below.

$$w_m(i,j) = \frac{(|v_m(i,j) - v_m^{BNF}(i,j)|) + M}{\sum_{n=1}^{L}(|v_n(i,j) - v_n^{BNF}(i,j)| + M)} \quad (2.2)$$

Where wm(i; j) is the weight term, $V_m(i, j)$ are the images in the multiband, $V_m^{BNF}(i,j)$ are the corresponding bilateral nonlocal means filtered images and M is a real number. Here weights capture the weak features and edges. Further appropriate selection of M value helps in retaining the removed edges in the final fused image. The fused image is given by,

$$v_F(i,j) = \sum_{m=1}^{L} w_m(i,j) v_m(i,j) \quad (2.3)$$

B. *Hyperspectral Image Denoising in Multiresolution Framework*

Hyperspectral images corrupted with i.i.d random noise have been considered which are further decomposed using DWT transform to obtain detailed and approximate coefficients. In hard thresholding, the wavelet coefficients below a given value are set to zero, while in soft thresholding the wavelet coefficient are reduced be a quantity to the threshold value. The proposed change in this technique is to apply a nonlocal means filter to the approximate coefficients as illustrated in Fig. 1

III. RESULTS & DISCUSSION

A. *Fusion of Hyperspectral Images*

We tested the proposed method on various hyperspectral image sets and reported results on two sets. The purpose of fusion here is to form a single image by merging possible features from all the source images. For evaluating the proposed algorithm quantitatively, we use statistical measures like entropy, mean, variance and average gradient and vision perception for qualitative measure. We compare results of hyperspectral image fusion with (a) wavelet transform: we have used similar approach as proposed in [8] however; inputs are replaced with hyperspectral images, (b) contourlet transform used in [9] and (c) bilateral approach suggested in [7]. In Table I we observe the proposed method outperforming all other techniques in comparison.

B. *Hyperspectral Denoising Multiresolution Framework*

The proposed multiresolution based work is experimented on Hyperspectral images. Images have been simulated with i.i.d random noise, with noise variation in the range σ=10~30.In Fig 2, we find BC (Bhattacharya Coefficient) and UQI (Universal Quality Index) values for hyperspectral images simulated for σ=10. It can be observed that the proposed method with SureShrink thresholding provides superior results compared to all methods.

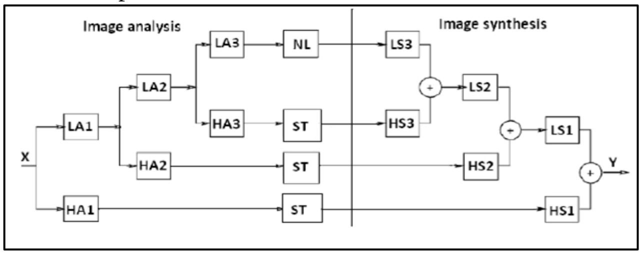

Fig. 1: Illustration of the Proposed Method of Denoising; NL and ST Denote Non-Local means and Soft Thresholding

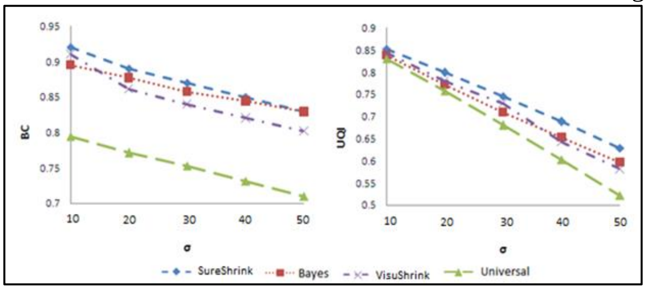

Fig. 2: BC and UQI Comparison for σ=10

Fusion method	mean	Std. dev.	entropy	gradient
Hyperspectral Set-I				
Wavelet [8] method	83.21	19.76	5.58	4.51
Counterlet[9] method	86.34	20.13	5.61	4.73
Bilateral[7] method	88.37	21.93	5.86	5.31
Proposed method	88.10	22.13	5.91	5.53
Hyperspectral Set-II				
Wavelet [8] method	88.84	20.23	5.93	4.37
Counterlet[9] method	85.39	21.12	6.05	4.61
Bilateral[7] method	87.39	23.32	6.41	5.28
Proposed method	87.61	23.51	6.24	5.46

Table 1: Comparative Fusion Results

Visual comparisons have been shown in Fig 3. Here we observe that wavelet transform technique blurs the image while denoising. Contourlet technique is able to retain the edges and small details better compared to wavelet. However the proposed retain the edges and small structural details better than both the techniques in addition to removing the noise quite substantially.

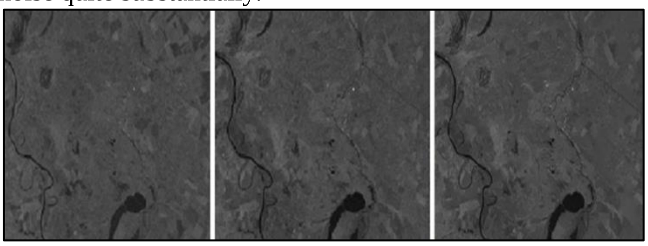

Fig. 3: Comparison of denoising results with Sureshrink thresholding (left to right): Denoised with wavelet transform, Contourlet transform and the proposed method

IV. CONCLUSION

In this paper we carry out all preprocessing techniques for hyperspectral images which are further used for automated crop monitoring system for precision agriculture. Hyperspectral images find applications in vegetation are identification, crop, and soil and plant disease classification. We obtain a single fused hyperspectral image containing thousands of narrow band hyperspectral images. We have used hierarchical model for fusion. Our proposed method outperforms all other techniques. In second work, we carry out denoising of hyperspectral fused image in a multiresolution framework. The proposed results are better than all other methods.

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