Research on Improved Destriping Algorithm with Spectral Moment Matching for Hyper-Spectral Images

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Abstract: Striping (banding or line) noise is a common anomaly which can be seen in hyper-spectral images. The existing destriping methods cannot be fully applicable to those sources. This paper presents an improved algorithm for correcting striping noise of hyper-spectral images. The algorithm is based on continuity of spectral space of hyper-spectral images to improve traditional moment matching method. High correlation existing in the bands of hyper-spectral images is the foundation of this improved algorithm which has better effect in image quality than tradition spatial autocorrelation. Several experimental results demonstrate that the improved algorithm can effectively repair the striping noise of hyper-spectral images. The evaluation results based on series of evaluation criteria of image quality index indicated that the image quality had been improved significantly after destriping.

Keyword: striping noise, hyper-spectral images, destriping, improved algorithm

I. INTRODUCTION

Striping noise is a very common phenomenon in many airborne and satellite imaging spectrometers images, mainly caused by the inconsistent response of the detector elements in the array and the output nonuniform signals [1]. The striping noise can obscure the true radiation information in the images, reduce the accuracy of hyper-spectral images, and have serious effects on the interpretation of remote sensing data and the extraction of information. Therefore, destriping has become an essential and fundamental preprocessing step in the procedure for applying hyper-spectral images. The problem of striping estimation and reduction in images has been widely analyzed in the past by remote sensing community [2-5]. Spectral moment matching methods strongly based on the spectral autocorrelation substitutes spatial autocorrelation to detect striping noise and repair the images [6].

In this paper, an improved algorithm using Spectral moment matching methods to estimate and remove striping in hyper-spectral data was proposed and described. The results obtained from real hyper-spectral images are presented and discussed. The image data was acquired by hyperion sensor mounted on the EO-1 space platform is analyzed in this paper.

II. MATERIALS AND METHODS

The Earth Observing 1 (EO-1) Hyperion is the only hyper-spectral sensor operating in space. However, the quality of some of the bands may be degraded due to insufficient energy within the narrow wavelength band captured by the sensor or the disturbance of water absorption [7]. Stripe noises are clearly undesirable in image classification and biophysical parameter extraction with Hyperion data. There are three different methods used in this paper
for destriping are given by: spatial moment matching \cite{8}, spectral moment matching \cite{6} and improved spectral moment matching.

a. Spatial Moment matching (SpaMM)

Spatial moment-matching method rests on the presumption that mean value and standard deviation of the signal in the along-track direction are practically same for all detectors. Therefore, striping is removed by matching the mean value and the standard deviation of the detectors in the same band with two reference values. Typically, such values are chosen as the mean and the standard deviation of the entire image in the same band.

b. Spectral moment matching (SpcMM)

Spectral moment matching method consists of estimating expected means and standard deviation for each along-track direction in hyper-spectral image data. The high correlation makes it possible to compare the statistics of image data in one band with those of corresponding detector in another highly correlated band, by averaging the measured means and standard deviations of corresponding along-track direction in a group of highly correlated bands.

c. Improved Spectral moment matching (ISpcMM)

SpcMM has suffered from a deadly drawback that it cannot remove stripes which are correlated between bands. A new destriping technique, improved spectral moment matching (ISpcMM) has been developed which does not suffer from the weakness of SpcMM. The ISpcMM is based on the continuity of spectral space and the high degree of correlation with band. The method is divided into three steps. Firstly, calculate the mean and standard deviation for each along-track column in the cube. Secondly, a desirable filter is adopted to the spectral of original image, then calculate gain and offset based on the original and estimated means and STDs for each along-track column. Finally, destripe each along-track column by applying the derived gain and offset to linearly transform the pixel values on the column. The overall flow chart of ISpcMM is summarized in Figure 1. The new algorithm has been used here to remove the striping from the original images.

Figure 1: the overall flow chart of ISpcMM

III. RESULTS AND DISCUSSION
From Figure 2 and Figure 3, we can find out that filter is a very important process step in ISpcMM. It can reduce the jitter from the surface of spectral and make the surface more continuous. There are so many stripes in the image that the filter windows size is too small when there is no apparent effect. In this paper, the filter windows size is 20.

![Figure 2: The schematic diagram of mean in spectral space](image)

(a) before filter  
(b) after filter

![Figure 3: The schematic diagram of standard deviation in spectral space](image)

(a) before filter  
(b) after filter

Both visual effects and quantitative assessment are applied in this paper to compare these three approaches and to prove the superiorities of ISpcMM. Figure 4 shows the images destriped by different methods.

![Images](image)

(a) Raw image  
(b) SpaMM image  
(c) SpcMM image  
(d) ISpcMM image
Figure 4: The result images of different destriping methods

Many assessing indices of images, mean, standard deviation value, SNR, Shannon entropy, skewness and kurtosis are applied in this paper to statistically evaluate the destriping results.

Table 1: The indices of each method used to evaluate destriping results

<table>
<thead>
<tr>
<th>Assessing Index</th>
<th>RAW</th>
<th>SpaMM</th>
<th>SpcMM</th>
<th>ISpcMM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>87.314</td>
<td>87.169</td>
<td>87.741</td>
<td>87.390</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>26.673</td>
<td>26.369</td>
<td>27.259</td>
<td>27.472</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.273</td>
<td>0.285</td>
<td>0.271</td>
<td>0.261</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>0.386</td>
<td>0.311</td>
<td>0.373</td>
<td>0.286</td>
</tr>
</tbody>
</table>

These indices listed in Table 1 adequately prove that the ISpcMM was the most effective among the three methods. The mean of this approach was the closest to the original mean. The standard deviation value and Shannon entropy value were greater than others, which stated that more details information was kept. Striping artefacts have been commendably removed in the ISpcMM according to the greatest SNR value. The skewness and kurtosis of the ISpcMM image were both less than other methods. In other words, the histogram was more symmetrical and the dynamic range of grayscale was wider those of others. The radiation of the ISpcMM image is more homogeneous because of the least distortion values of edge radiance and gain adjustment amount all.

In summary, the improved spectral moment matching was more effective with higher accuracy than other two methods.

IV. CONCLUSION

Destriping is an important pre-processing step in quantitative analyses procedure using hyper-spectral images. An improved approach based on spectral moment matching is described in this paper for the removal of striping noises in hyperion data. In the analyzed cases, the algorithm yields very good performance as confirmed by the values of the index evaluated over the channels where striping noise is more evident. The comparison with the moment matching has shown that the ISpcMM provides better performance on reducing the striping noises, preserving the signal, and avoiding distortions. However, there are still some problems unsolved in this paper that should be the focuses of future researches. As for filter to the original image, it is difficult to automatically select the frequencies of stripes, which is realized manually in this paper. In addition, six-index quantitative evaluators used in this paper are a little complex, which ought to be simplified with less but reasonable indices.

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REFERENCES


