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Removing the Stripes Caused by the Failure in Detector 4 of Band5 of MODIS Sensor

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Abstract: MODIS sensor is a hyperspectral sensor on board of Terra and Aqua platforms and images every one or two days the entire surface of the Earth in 36 spectral bands. Over time, some detectors of these sensors show malfunctioning and some are stopped working. In this paper, using reflectance values of sounddetectors for the invariant surfaces, a linear relationis proposedto remove stripping from the images. In this method noise modification is done partially and because the technique only influences the noisy detectors and has no effect on other detectors, it is expected to have novelty.

Keywords:MODIS, Noise, detector, stripe, image, remote sensing.

I. Introduction

The presence of noise in the detectors embedded in the MODIS sensor, may cause destruction of information. One of the main reasons for the emergence of stripping noise in satellite images, is malfunctioning and sometimes inappropriate calibration of the detectors acquiring those images. Each row in the satellite images acquired by the MODIS sensor, will be picked up by a particular detector. Now if the gain and offset of the neibouring detectors are not compatible with each other, the stripped patterns are created in the image.

Gamly in 2002 stated that MODIS data is affected by three kinds of noise i.e. detector to detector, mirror (band) stripping and noise stripping [i].

stripping of detector to detector is determined by a specified pattern and repetitive stripping (uniform) throughout the image. These lines are mostly created through relative gain and offsets between detectors of in a particular band [ii]. Mirror Stripping is the sudden change of the bias level in all detectors. This change is created during the rotation of the scan mirror and the extent of this change is almost constant [iii]. Noise stripping are created because of the small errors in internal calibration system, variations in detectors responses, and random noise. In the information collected by the MODIS sensor, the noise stripping is mostly created in thermal band and is worsened over time [iii].

Many efforts have so far been implementedbyMODIS administrationto modify the damaged detectors and always give a table for each set of detectors in which the number of damaged and unusable detectors are specified in (https://mcst.gsfc.nasa.gov/calibration/time-dependent-list-non-functional-or-noisy-detectors).

By monitoring the behavior of the reflectance during the working period of this sensor the behavior of its detectors in band 5 can be evaluated. To identify those detectors with stripping noise it is assumed that the first row of the main image of band 5 is produced by the first detector of the sensor in this band.

Since the band 5 has a resolution of 500 meters, the image is picked up by an array of 20 detectors in the sense that with every scan of the mirror, 20 rows are taken simultaneously [v]. These detectors are located side by side directed along the sensor flight and in each pickup one linear array is recorded by them [vi].Through plotting the reflectance behavior for a homogeneous invariant surfaces, the performance of detector 4 of this sensor in band 5 is found different from compared to the other detectors where this shows to have problem. Therefore the detector (4) can be introduced as the malfunctioning detector in band 5. Figure 1 shows the reflectance of all detectors in band 5 during 15 years for pixels of surface of desert and deep ocean.

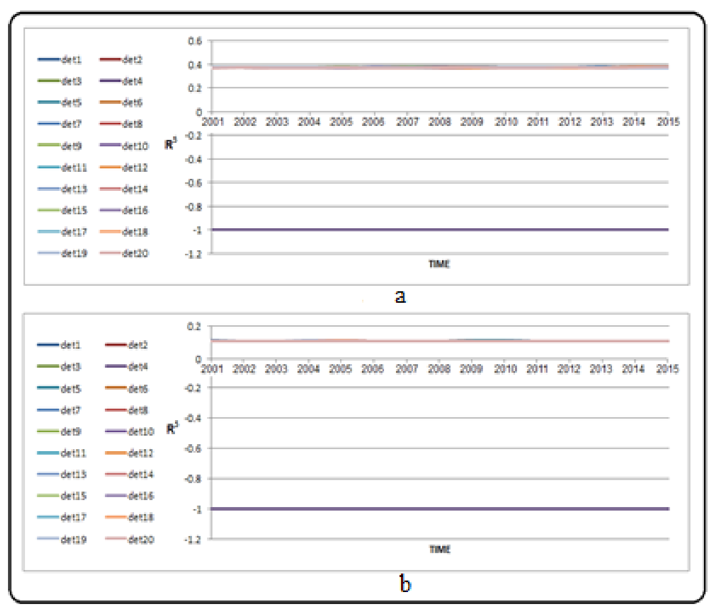

Figure 1- Reflectance of the detectors of band 5 of the MODIS sensor during 15 years a) from the desert surface b)

from the deep water. It is seen that the reflectance behavior of the detector 4 relative to the other detectors is different.

II. Material and Methodology

In this paper, the images of MODIS level1B is used. This image is the same as the level 1A but corrected in terms of geometry and radiometric [vii]. In figure 2 the image acquired by MODIS sensor on 2 August 2015 in band 5 is shown. As can be seen, the stripes are observed as an alternating pattern throughout the image

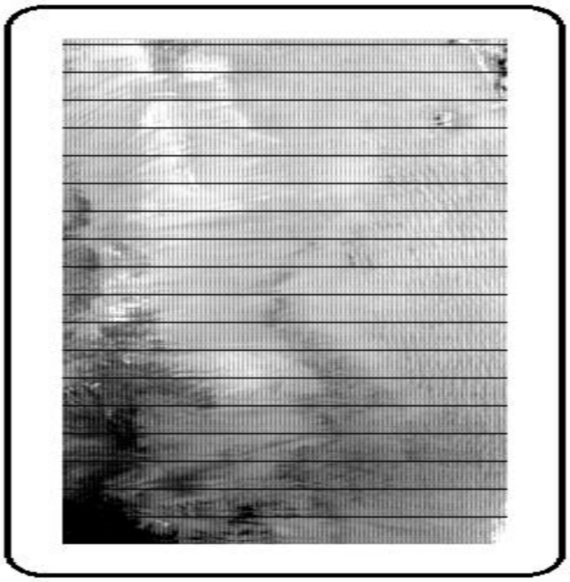

Figure 2- The image acquired by the MODIS sensor in 2 August 2015 (band 5).

and it states that the detector 4 of band 5 of this sensor is damaged.

In MODIS level 1B products, usually the pixels related to the disabled detectors are filled by the average of neighboring pixels. This only improves the image visually but may work when the surface is homogeneous where the neighboring pixels have similar however. However, when the surface cover of the surrounding pixels are different, the pixel reflectance value are different and averaging may cause stripping to remain. Therefore using the neighboring pixels does not seem an appropriate method. In this paper in order to recover the detector 4 of band 5, the detector 4 of band 7 which is collected from the same region as detector 4 of band 5 is used. Figure 3 shows the relationship between detectors of band 5 and the corresponding detectors of band 7 in the appropriate ground surfaces (desert and deep water). It is observed that there is a linear relationship between the corresponding detectors of these bands.

Table 1 shows the slope and offsets of linear relationships between detectors 3 and 5 of band 5 and the corresponding detectors in band 7. In this table R^x_y is the reflectance of the detector y in band x. In other words R is the reflectance, x is the band number and y is the number of detector. A and B are the slope and offset coefficients of the linear model.

In the next step, a linear relationship is obtained between detector 3 of the band 5 and detector 4 of band 7 which can be used in the noise improvement. For further examination the relationship

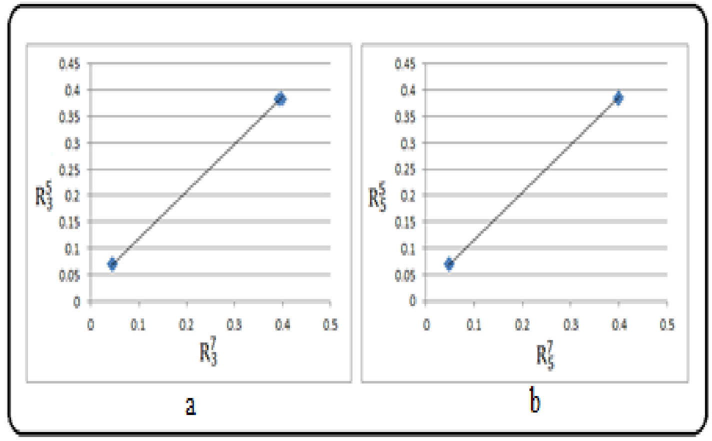

Figure 3- a) Linear relationship between detector 3 of band 5 and the corresponding detector in band 7, b) linear relationship between detector 5 of band 5 and the corresponding detector in band 7

Table 1- Relationship between detectors 3 and 5 of band 5 and corresponding detectors in band 7

	A	B
R^5_3=0.8992 R^7_3 + 0.0283	0.8992	0.0283
R^5_5= 0.8982 R^7_5 + 0.0257	0.8982	0.0257

Table 2- Relationship between detector 3 and 5 of band 5 and detector 4 in band 7

Equation	A	**B**
R^5_3=0.8985 R^7_4 + 0.0237	0.8985	0.0237
R^5_5= 0.902 R^7_4 + 0.0236	0.902	0.0236

between detector 5 of band 5 and detector 4 of band 7 is used for the recovery of the damaged detector of band 5. In table 2 the relationship between detector 3 of band 5 and detector 4 of band 7 and also relationship between detector 5 of band 5 and detector 4 of band 7 is is given.

Since the reflectance from the surface of the desert andfrom deep water have the maximum and minimum value respectively and other surfaces with different covers have reflectance values somewhere in between so it is expected that the equation of the correction can be used for the all surfaces with variety of covers.

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III. Results and Tables

For evaluation of the results obtained from the present method, the root mean square error RMSE (equation 2) and relative error (equation 3) are [viii].

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{N}(x_i - y_i)^2}{N-1}} \quad (2)$$

$$\text{Relative error} = \frac{\text{RMSE}}{\text{Average}} \times 100 \quad (3)$$

Where x_i is the uncorrected pixel, y_i is the modified pixel and N is the number of pixels.

The result are shown in table 3.As can be seen from table 3, low values of the RMSE and relative error are indicators of the Method presented in this work which gives better results specially when using the linear relationship

Table 3- Statistics of RMSE and relative error

Equation	RMSE	Relative error (%)
Using the linear relationship between detector 3 of band 5 and detector 4 of band 7	0.08	2.1
Using the linear relationship between detector 5 of band 5 and detector 4 of band 7	0.09	2.4

between detector 3 of band 5 and detector 4 of band 7, so this equation was used for removal of the detector 4 stripes. By applying this correction method on the stripped image, it is possible to improve the image only at the stripped location leaving other pixels intact (Fig. 4).

Figure 5 (a) shows the scatterplot of uncorrected versus destripped image (figure 4) in band 5. Since this method impacts only on the noisy pixels and has no effect on other pixels therefore for the regions without noise the scattered points are laid on 1:1 line while the regions with zero values before correction have various values on the x axis after applying correction. This scattered values depend on the reflectance of the surface cover. If the surface is uniform, all points are in one region but in the case that the surface cover of the surrounding pixels are different, scattered data will be on the x axis. This shows that the model has done well.

Also in figure 5 (b) the x-profile curve of the detector 3 of band 5 and detector 4 of band 7 after correction is shown. In this curve the behavior of the detector 3 and corrected detector (detector 4) is shown with color green and red respectively. As can be seen, detectors have similar behavior relative to each other and this indicates that the band 7 is an appropriate choice for recovery of the malfunctioned detector.

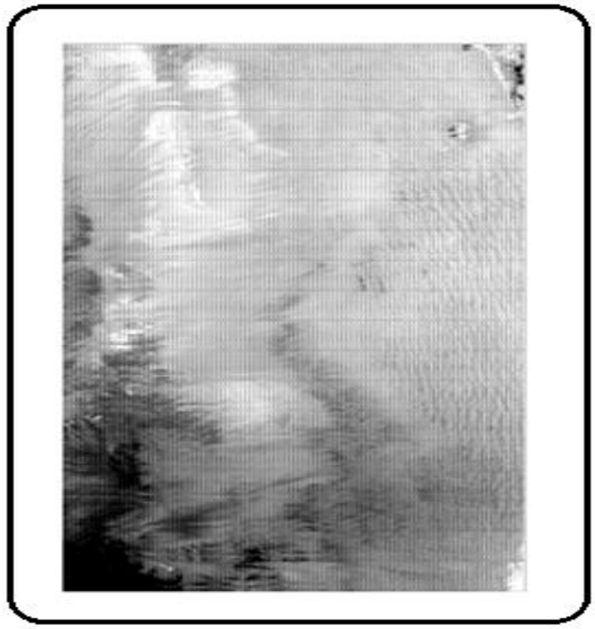

Figure 4-Result of the stripping removal using the proposed method.

In general, the proposed method demonstrate high accuracy. This is because in this method, initially, the noisy detectors are identified and then the undamaged detectors are used for the correction of the damaged detectors. In other word this method acts only on the noisy detectors and has no affection on other not noisy regions and therefore is reliable accuracy.

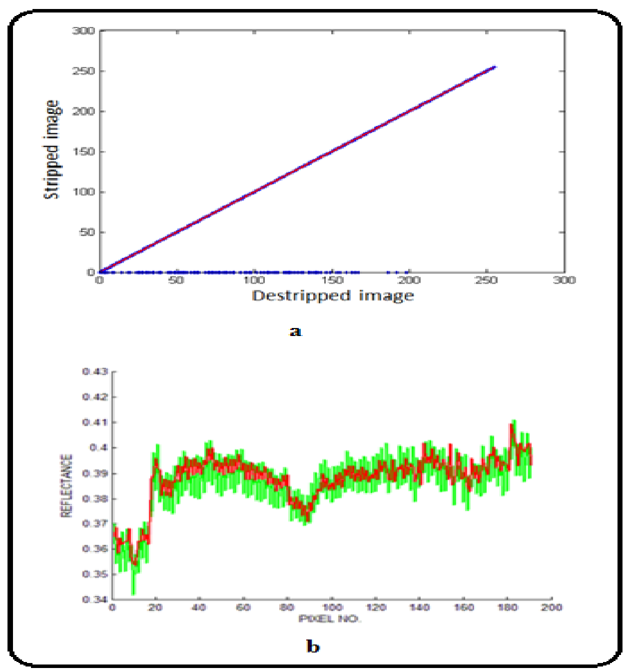

Figure 5- a) Scatterplot of the corrected and uncorrected image of figure 2 and image of figure 4, b) x-profile of the detector 3 of band 5 and detector 4 of band 5 after correction

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IV. Conclusion

In this paper a linear equationfor the removal of the stripped pixels present in the imageacquiredby detector 4 of band 5 of MODIS sensor is presented. The adjusted results indicate that the minimum error in the correction of this detector's readings is associated with the correction coefficients between detector 3 of band 5 and detector 4 of band 7.

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