TECHNIQUE TO RECONSTRUCT BAND 6 REFLECTANCE INFORMATION OF AQUA MODIS

Andy Indradjad*), Noriandini Dewi Salyasari, and Rahmat Arief
[1]Remote Sensing Technology and Data Center LAPAN
*)e-mail: anindra26@gmail.com

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Abstract. Remote sensing data could experience damage due to sensor failure or atmospheric condition. Reconstruction technique to retrieve the missing information had been widely developed in the past few years. This writing aimed to provide a technique to recover reflectance information of Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) Band 6. Since Band 6 Aqua MODIS experienced sensor failure, lots of information would be missing. There were three kinds of methods used in repairing such damage. Two of which were categorized as spatial-based methods, i.e. NaN interpolation method and tensor completion method. Whereas, another method was a spectral-based one. NaN was an interpolation method to reconstruct missing value; while tensor completion method utilized low rank approximation, and spectral method used correlation between Band 6 and Band 7 which had near wavelength. Implementation of these methods was resulted in reconstruction of Aqua Modis Band 6 data which was damaged due to detector disfunction on Aqua Satellite. Peak Signal to Noise Ratio (PSNR) value of this method was 41 dB, meaning that reconstruction technique provided positive impacts for data improvement.

Keywords: *data reconstruction, MODIS band 6, Aqua*

1 INTRODUCTION

Low resolution remote sensing data which could be obtained from Terra/Aqua satellite for free, had long been used in Indonesia to monitor weather, forest fires and drought through green plantation, as well as to predict potential fishing zones (Kushardono *et al.,* 2001). In 2013, National Institute of Aeronautics and Space (LAPAN) as governmental agency which was responsible for providing remote sensing data, had increased the capacity of its ground stations to receive (acquire) satellite data with low, medium and high resolutions for the whole of Indonesia region such as those from: Terra/Aqua, NPP, Landsat-7, LDCM, SPOT-5, and SPOT-6 satellites through Remote Sensing Ground Station in Parepare, South Sulawesi (Pusfatja, 2015). MODIS remote sensing data could be utilized not only on land, sea and air, but also for daily application, interdisciplinary and knowledge environment (Salomonson *et al.*, 2002). Band 6 Aqua MODIS could be utilized to calculate Enhanced Vegetation Index (EVI) for rice harvest estimation (Dirgahayu *et al.*, 2014).

Considering the importance of low resolution image data, it was expected LAPAN could provide clear and accurate MODIS data. MODIS image had specific wavelength, spectral radiance and Signal to Noise Ratio as seen in Table 1-1. Yet since 2014, low resolution MODIS images produced by Aqua satellite had experienced damage on one of its spectral value, i.e. on its Band 6 (Wang *et al.*, 2016).

MODIS Band with nadir spatial resolution of 250 m (Band 1-2) had 40 detectors/band, those with spatial resolution of 500 m (Band 3-7) had 20 detectors/band, and those with spatial resolution of 1.000 m (Band 8-36) had 10 detectors/band. Band 1-19 and 26 were Solar Reflective Bands (RSB), while the rest were bands that emit thermal (Thermal Emissive Bands/TEB). There was totally of 36 spectral bands distributed according to their wavelength on four focal plane assemblies (FPAs) consisted of data visible (VIS), near infrared (NIR), short and mid-wave infrared (SMIR), and long-wave infrared (LWIR) (Xiong *et al.*, 2004).

Table 1-1: MODIS image specifications and signal ratio

Band	Central Wavelength (μm)	Band width (μm)	Spectral Radiance (W/m² -μm –sr)	SNR (Signal-to-Noise Ratio)
1	0.645	06.20-0.670	21.8	128
2	0.858	0.841-0.876	24.7	201
3	0.469	0.459-0.479	35.3	243
4	0.555	0.545-0.565	29.0	228
5	1.240	1.230-1.250	5.4	74
6	1.640	1.628-1.652	7.3	275
7	2.130	2.105-2.155	1.0	110

Disturbance on Band 6 Aqua MODIS hindered 15 of 20 detectors within the wavelength (1.628 – 1.551 μm). The noise was caused by ineffective sensor disturbance and atmospheric influence. Damage on spectral value of Band 6 had resulted in data stripping. Stripping was a serious problem, since it caused some parts of the image or information to disappear, and resulted in un-optimal utilization (Wang *et al.*, 2006).

Disturbance to Band 6 Aqua MODIS had caused up to 75% damage on image data. Only five of 20 detectors on the image were valid. Reconstruction took reorganization of the image to get a better output on Band 6 Aqua MODIS low resolution image. Reconstruction technique was performed by projecting pixel movement during registration process. This projection process was performed through calculation to obtain unknown pixel values or complement recognized pixel value (Wheeler *et al.*, 2005).

To reconstruct missing information of a remote sensing data was an issue to be resolved. It was because every pixel on remote sensing data was very valuable in order to achieve precise information. Thus, it needed consistent method to estimate the remaining pixels value. Various methods had been implemented to reconstruct lost data. The methods included spatial-based method, i.e those utilizing current data rather than using additional information from other image (Shen *et al.,* 2015), interpolation method and tensor completion method included in this mechanism. The second method was by using spectral value-based method, i.e. those that extract missing spectral information from other spectral values. The third was temporal-based, i.e. method which utilized other data received on the same position over distinct time. The fourth mechanism was using a hybrid method which combined three previous approaches (Shen *et al.,* 2015). NaN interpolation method had already been studied in the proceedings of National Seminar on Remote Sensing 2016 (Indradjad *et al.*, 2016). So this research is aimed to further.

The goal of this research was to reconstruct missing information on Band 6 Aqua MODIS by using spatial-based method and to compare those with spectral-based methods. Both method could correctly restore missing information, and might have operational function in accordance with user needs.

2 MATERIALS AND METHODOLOGY

2.1 Data

Data used in this analysis were Band 6 of Aqua and Terra MODIS imageries dated June 2, 2016. The data were acquired from Ground Station of Technology and Data Center, National Institute of Aeronautics and Space (LAPAN). Size of the data was cropped into 512 x 512 pixel.

2.2 Methods

The methods used to reconstruct missing information in this paper were spatial-based methods, namely interpolation and tensor completion methods, as well as spectral-based method of Band 7. To measure the ability of each method, they are applied to error-simulated terra data, and then compare the result to the original data. Generak Signal to Noise Ratio (PSNR) of the result data were then be compared to the original data. The bigger PSNR values, the more similar ity two data statistically.

2.2.1 Spatial Method

Spatial-based method was very traditional. It essentially was a method which needed no tool or other information source in reconstructing lost information. Spatial-based method used part of data itself to make improvements. In terms of data reconstruction, this method had an underlying approach that missing information and the remaining data could be found in the same statistic and geomatic structure (Shen *et al.*, 2000). Spatial-based method utilized correlation of local and non-local information in a data/image. This method could also be utilized in processing remote sensing imagery.

One kind of spatial method which was widely used during processing stage was interpolation. This method played an important role in digital image manipulation. Interpolation mean performing the process approach in mapping pixels of image data to allow changes. Mapping in this case mean effort to achieve the best result from surrounding pixels. The result of the interpolation method varied greatly depended of the input data and the method used. Algorithm commonly used in interpolation method was linear interpolation. Linear interpolation was the simplest type. Basically, linear interpolation calculated the midpoint (median) of two points. Linear interpolation had an advantage of quick and easy process (Hadi, 2016). Spatial interpolation had two assumptions i.e., continuous and interconnected attributes. Both assumptions implied that attribute data prediction could be derived based on data from nearby locations and adjacent pixels value would have more similarity than pixels far apart (Hadi, 2013). Linier interpolation applied sequence of polygonal points, in which a straight line connected two points in a row. Therefore each point (P; Q) was independently interpolated by using formula 2-1.

$$P(t) = (1-t).\ P + t.Q \qquad (2\text{-}1)$$

Where t is 0 to 1 variance (Gomes, 2010).

Linear interpolation method was usually applied by connecting points on data with NaN; thus the mechanism was widely known as NaN Interpolation. This method offered several different approaches that provided positive feedback in terms of accuracy, speed and memory which were crucial to carry out this method. NaN interpolation was based on linear algebra and PDE discrete. This approach developed a system to change unknown value into certain value. In case data was small size, the method was quite fast and efficient.

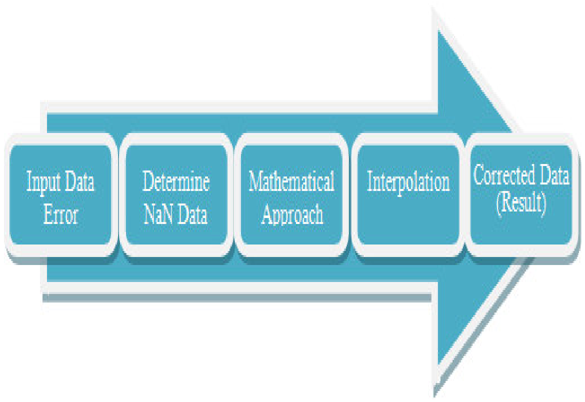


Figure 2-1: NaN Interpolation Flowchart

As for the details of NaN interpolation method was as follow, and the process of this method was depicted in Figure 2-1 below (Indradjad *et al.*, 2016):

- Input Data Error: Data to be input in this method was the result of acquisition i.e. Band 6 reflectance information of Aqua MODIS.
- Determine NaN Data: First, determine the value of error data and replaced it with NaN value.
- Mathematical Approach: Calculate partial derivative difference on rows and columns of image to be corrected. Mathematical approach used was Partial Deferential Equation (PDE) for interpolation (Bae and Weickert, 2010). This approach implemented Formula 2. Image S was finished by solving diffusion equations with S_0 as the initial guess.

$$\frac{\partial x}{\partial t} = \Delta_{S(t)^x} \text{ on } S(t)\times[0,\infty)$$
$$x = x^{know} \text{ on } \partial S(t)\times[0,\infty]$$
$$S(0) = S_0 \qquad (2\text{-}2)$$

- Interpolation: Finished completion by replacing NaN data with mathematical calculations of surrounding pixel values.
- Corrected Data (Result): Reconstruction result data using NaN interpolation method.

Another spatial-based method was tensor completion. This method used Low Rank Tensor Completion (LRTC) approach to complete convex equation. This method could be utilized to repair up to 80% damage (Liu *et al.*, 2013). Three parameters required to complete tensor equation were α (relaxation parameter), β (value which could be set to 1), and DΓ́ (weights of the trace norm terms). Those parameters determined the outcome of completion result of low rank approximation approach (Liu *et al.*, 2013).

2.2.2 Spectral Method

Spectral method was applied in this research to find the correlation between Band 7 Terra MODIS and Band 6 Terra MODIS. From this correlation process, Band 6 value would be obtained from Band 7, so that the previous band of MODIS Aqua might be reconstructed. The formulation was: (Wang et al, 2006)

$$R_{B6} = 1.6032R_{B7}^3 - 1.9458R_{B7}^2 + 1.7948R_{B7} + 0.012396 \qquad (2\text{-}3)$$

In which:

R_{B6} was Band 6 value
R_{B7} was Band 7 value

Equation used in this method was polynomial order 3, which yielded the best correlation for Band 6 (Wang *et al.*, 2006). This equation could also be combined with matching histogram and local least square (Rakwatiin *et al.*, 2009).

3 RESULTS AND DISCUSSION

Damage on original Band 6 reflectance information of Aqua MODIS could be seen in Figure 3-1. Data reconstruction of NaN interpolation method, tensor completion method and spectral method could be seen in Figure 3-2a, 3-2b and 3-2c sequentially. We could clearly see that the result of tensor completion reconstruction was the worst completion, compared to the other methods. NaN interpolation method and spectral method were able to reconstruct missing Band 6 Aqua MODIS image.

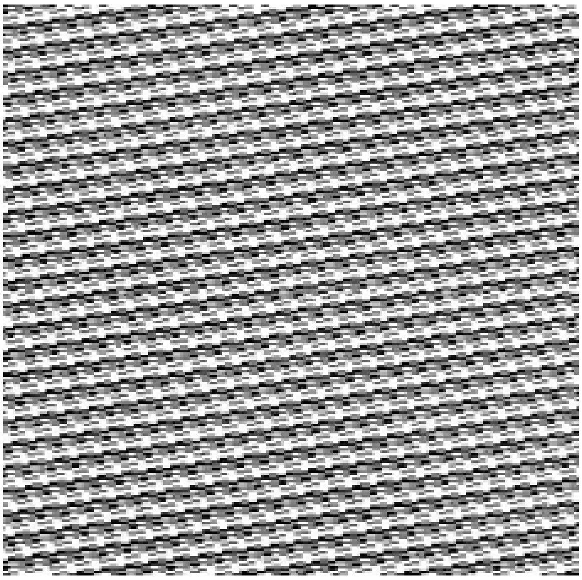
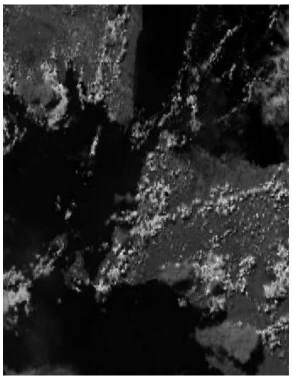
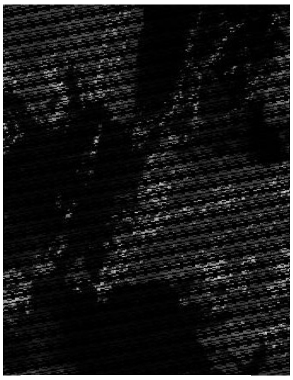


Figure 3-1: Original Band 6 Aqua MODIS image



(a) Result of NaN Interpolation



(b) Result of Tensor Method

(c) Result of Spectral Method

Figure 3-2: Band 6 Aqua MODIS Reconstruction Result

Result of reconstruction on Band 6 Terra MODIS data was acquired by simulating Aqua satellite error. Band 6 Terra MODIS data and the error simulation could be seen on Figure 3-3a and 3-3b sequentially. The result of reconstruction on Band 6 Terra MODIS image (error simulation) to restore damaged data by using NaN Interpolation method could be seen in Figure 3-4a, tensor completion method in Figure 3-4b, and spectral method in Figure 3-4c.

As the result data were reviewed visually, it showed that tensor completion method could not fix the data well, due to visible presence of striping although the line was not as clear as pre-reconstruction and the result image was clearer. This was due to geometric error and consistent error repetition, although randomly it would be able to repair up to 80% lost data (Liu *et al.*, 2013). Error could also be caused by non-geometrical image, or repetition as those in chess form, and building (Liu *et al.*, 2013).

NaN Interpolation method had greater ability than the other methods, although it had repetitive and regular error. It was clearly visible that the corrected image was almost similar to the original data.

Meanwhile, band reconstruction using spectral method seems to experience distortion. The result was contrasts to previous study conducted by Wang et al (2006), and preliminary research by Rakwatiin et al (2009), which showed positive correlation between Band 6 and Band 7. This was due distortion and minute damage on Terra MODIS Band 7 as seen in Figure 3-5b. The damage reduced the ability to reconstruct itself dropped considerably, because image was produced from broken spectral bands. However implementation of spectral method on Aqua MODIS had better result than those Terra satellite.

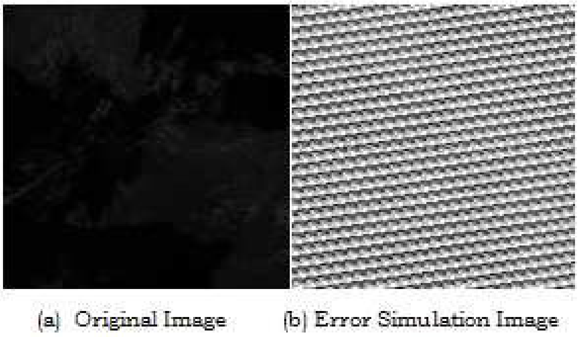


Figure 3-3: Terra MODIS Band 6

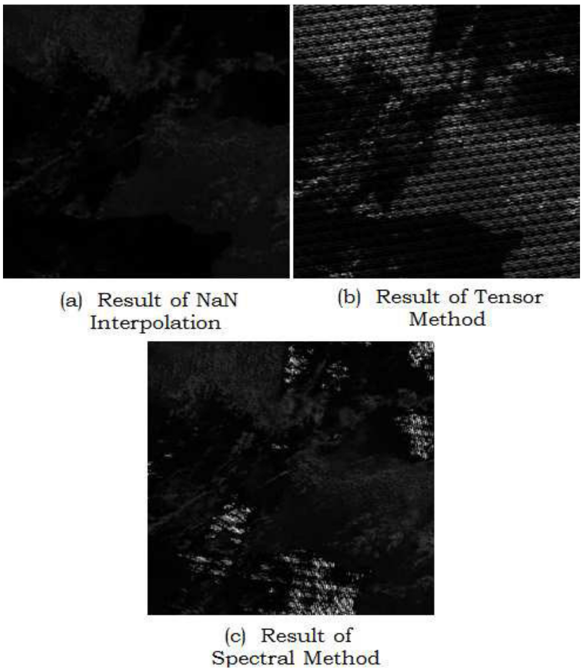


Figure 3-4: Result of Reconstruction Terra MODIS Band 6

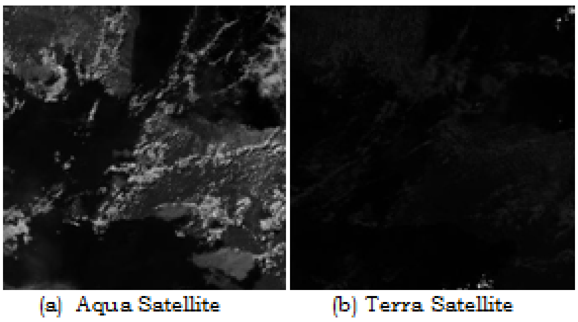


Figure 3-5: MODIS Band 7

Table 3-1 presented the value of Peak Signal to Noise Ratio (PSNR) and Root Mean Square Error (RMSE) which compared the original image and reconstruction results for each method performed on Terra MODIS data. High PSNR value indicated better or closer similarity to the original picture; while conversely high RMSE value represented worse or more differences from the original data.

Thus, in terms of PSNR and RMSE values, NaN method had better ability than two other methods. Tensor completion method had the lowest ability to reconstruct Terra MODIS Band 6, although it had better PSNR value than spectral method. It was due to results which could be seen visually.

Table 3-1: PSNR Value of Band 6 Terra MODIS Data against Original Data

Data Image	PSNR (dB)	RMSE
Result of NaN Method	40.97	2.2807
Result of Tensor Method	28.54	2449.5
Result of Spectral Method	19.09	110

Spatial method was beneficial when one had trouble in determining which spectral band to replace, especially if the spectral band with high correlation was damaged, as the case of MODIS Terra Band 7. However spatial method relied on the type of error was found in the image and the image's geometric shape. It could be seen on the failure of tensor completion method to reconstruct Band 6 data of either MODIS Terra or Aqua. Spatial method which showed better performance in this research was PDE-based NaN Interpolation. This method was able to improve images both visually as well as statistically with PSNR and RMSE eventhough it still showed small margin of error.

4 CONCLUSION

Aqua MODIS data experienced sensor failure on one of ots spectral values, i.e. Band 6. This condition caused stripping on the image. Similar disturbance also occurred in Band 7 Terra MODIS eventhough the damage was yet as comprehensive as those in Aqua MODIS.

By implementing PDE-based NaN interpolation method, the imagery data would have a better performance, compared to other two methods in reconstructing Band 6 Aqua MODIS. PSNR value of this method was 41 dB. It mean that this information reconstruction technique provided positive impacts. Compared to the original image, reconstructed data had better improvement, even though the differences were invisible visually.

Spectral-based method has advantage if the data used for reconstruction has no error, for this case the band 7 data has several error which influenced the result, and make it has make more error compare to other two technique. Tensor method has the worst result compare to other method, it still has stripping on the result even it has better performance in PSNR and RMSE compare to spectral-based method.

Studies on technique to reconstruct missing reflectance data was needed in the future. Thus high quality data could be acquired. It was as Well to anticipate similar things from happen on satellite operation hence forward.

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