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Comparative Study of Relative Radiometric Normalization using No Change Set

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Abstract*: Satellite images involves radiometric errors as well as geometric errors, these errors should be normalized. For radiometric correction of satellite images there two main methods are useful, absolute radiometric normalization and relative radiometric normalization. Relative radiometric correction has number of applications in weather and climate studies, crop studies, detection and removal of cloud, change detection and so on. The image distortion due to cloud cover is a classical problem of remote sensing imagery. Especially, for non-stationary satellite, it is commonly found in the earth resource observation application. Removing cloud cover from satellite imagery is very useful for assisting image interpretation. Hence cloud detection and removal is very vital in processing of satellite imagery. For detection and removal of cloud relative radiometric normalization using no change set (NC) technique is proposed here in spatial domain as well as in frequency domain. The cloudy image is radiometrically normalized by using reference image of same area, acquired at different date. The visual appearance results, statistical results and histogram results are discussed.

***Index Terms*: Normalization, No Change Set, Radiometric, Relative.**

I. INTRODUCTION

Relative radiometric correction is aimed towards reducing atmospheric and other unexpected variation among multiple images by adjusting the radiometric properties of target images to match a base image, thus it is also called relative radiometric normalization. Relative radiometric normalization is an image based correction method achieved by setting the multi-temporal images into a within multiple scenes can be used to render the scenes to appear as if they were acquired with the same sensor, with the same calibration, and under identical atmospheric conditions, without the need to be absolutely corrected to surface reflectance. Most relative methods assume that radiometric relation-ships between the target image and the base image are linear. A base image, selected to represent some common scale, is not required to be the most accurate reflectance estimation. The relative radiometric normalization method can correct noise deriving from the atmosphere, sensor, and other sources in one process, and is therefore widely used. Generally, relative normalization methods are simpler than absolute normalization methods.

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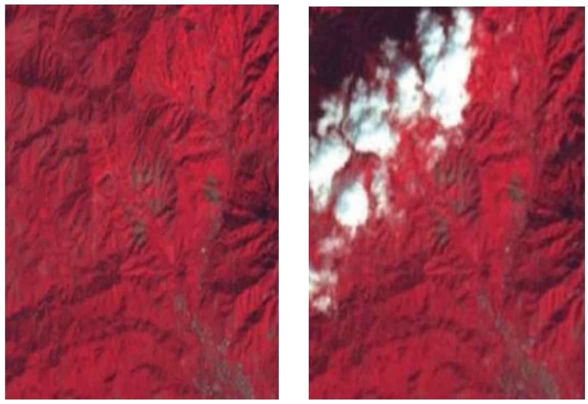
The relative radiometric normalization method is proposed here for detection and removal of cloud. The clouds are a mass of water or ice in the atmosphere that generally produces rain or other forms of precipitation. The detection of clouds in satellite imagery has a number of important applications in weather and climate studies. For many applications however, Clouds are a contaminant whose presence interferes with retrieving atmosphere or surface information. In these cases, the detection and removal of cloud contaminated pixels in satellite imagery is important. The cloud is detected here by using average brightness threshold algorithm, by selecting proper average brightness and threshold value cloud is successfully detected. For the detection of cloud relative radiometric normalization using no change set method is proposed using spatial domain and frequency domain, by calculating normalized correlation clouds are successfully removed and results are discussed by using visual appearances, statistical and histogram analysis.

II. METHODOLOGY

The image dataset used in this study is obtained from LANDSAT ETM+ [21]. Figure 1(a) is the reference image and Figure 1(b) is the subject image. The subject image which is cloudy image, radiometrically normalized by using relative radiometric normalization using no change set method.



(A) (B)

Figure (1): (A) reference image, (B) subject image

A. Cloud Detection

For the detection of cloud average brightness algorithm(ABT) is used here. In average brightness algorithm first average brightness of the subject gray image is calculated, on the basis of this average brightness value threshold value is calculated. This threshold value is applied on subject image to separate the cloudy and cloud free regions. The flow of the average brightness algorithm is shown in Figure (2).

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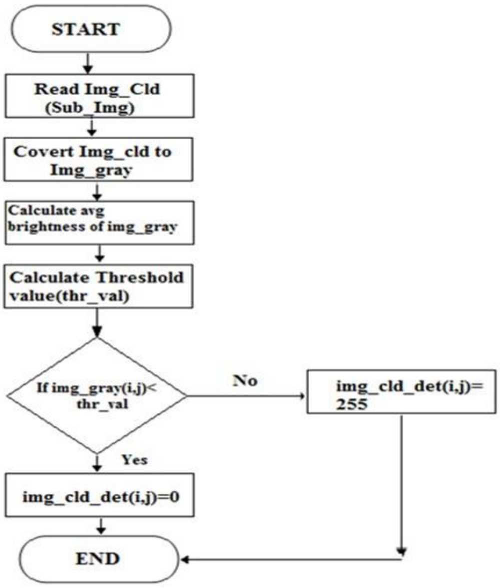

Figure (2): Flowchart of average brightness algorithm.

For accurate determination of threshold value (t), ABT uses average cutoff function[9].
This cutoff function is determined as

$$Cutoff = Avg_{brightness} + f \times \left(\ln(G_{MAX}) - \ln(Avg_{brightness})\right) \quad (1)$$

Where, ln() denotes the natural logarithm, G_{MAX} is the no of gray values and f is multiplicative coefficient, determined empirically. According to this threshold value(cutoff) divide image into cloudy and cloud free regions. Figure 3 shows cloud detected subject image.

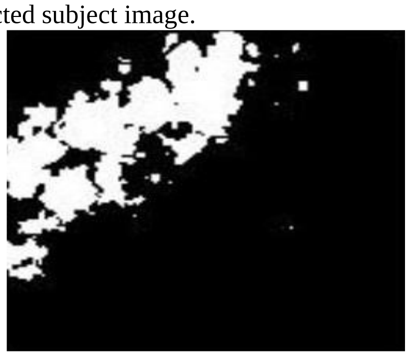

Figure 3: cloud detected subject image

The clouds are successfully detected here, after cloud detection, apply the proposed normalization method to remove the cloudy regions.

B. Cloud Removal

There are mainly two methods are used for radiometric correction one is “Absolute Radiometric Normalization” and other is “Relative Radiometric Normalization”, out of these two methods, Relative Radiometric Normalization method is Proposed here. Relative radiometric normalization method is again divided in, Statistical adjustment, Histogram matching ,Linear regression normalization techniques. Out of which linear regression technique is used here. This technique works on principal that the sample pixels of same area at different date are linearly related. Linear regression normalization technique has divers of sub methods, such as pseudo invariant features (PIF), Image regression (IR), No change Set (NC). Out of these methods relative radiometric normalization using no change set method is proposed here.

C. Relative Radiometric Correction using No Change Set Normalization

The No Change Set (NC) method is proposed here, for that purpose two images of same scene but different dates are used. In which cloud free image is called reference image and cloudy image is called subject image. This method assumes that pixel samples at day one are linearly related to the pixel samples for the same location at day two, according to that principle the subject image is radiometrically normalized by using reference image in spatial domain and frequency domain.

No change set normalization in spatial domain

In spatial domain, it operate directly on the input image pixel array that is direct manipulation of pixels in an image. For normalizing the cloudy image, the subject image is compared with reference image and no change set is determined to detect the cloudy regions and these cloudy pixels then replaced with uncloudy set of reference image. The size of reference and subject image is 256x256 is taken here. The schematic of normalization process is shown in Figure 4. The images for this data set are taken from Resourcesat-1 LISS III sensor[9].

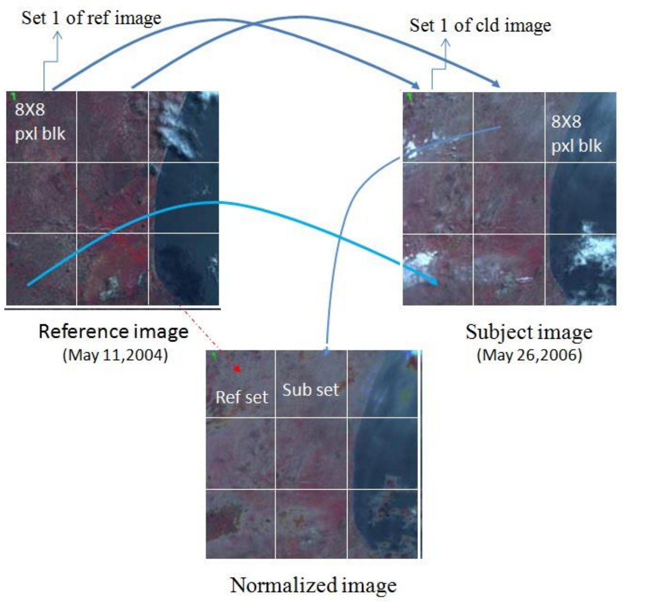

Figure 4: The schematic of normalization process

As per shown in Figure 4 the reference and subject image of size 256x256 are divided into block size of 8x8 pixels, then normalized correlation between set 1 of reference image and set 1 of subject image is calculated. The normalization correlation is derived from following equation.

$$Nc = \sum_{i=1}^{n}(X_i - \bar{X}_i)(Y_i - \bar{Y}_i) \Big/ \sqrt{\sum_{i=1}^{n}(VX_i * VY_i)} \quad (2)$$

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Where,

X_i is digital numbers of reference image block set

Y_i is digital number of cloud image block set

VX_i and VY_i are the variance of reference image block set and cloudy image block set respectively

$\overline{X_\iota}$ and $\overline{Y_\iota}$ are the mean of reference image block set and cloudy image block set respectively

The Mean and variance are calculated as,

$$Mean = \overline{X_\iota} = \frac{\sum_{i=1}^{n} X_i}{n} \text{ and} \quad (3)$$

$$variance = VX_i = \frac{\sum (X_i - \overline{X_\iota})^2}{n} \quad (4)$$

Thus if no change subset is identified, the normalization coefficient are determined from following equations

$$a_i = \frac{vy_i}{vx_i} \; b_i = \overline{y_\iota} - a_i \overline{x_\iota} \quad (5)$$

where,

VX_i and VY_i are the variance of reference image block set and cloudy image block set respectively

$\overline{X_\iota}$ and $\overline{Y_\iota}$ are the mean of reference image block set and cloudy image block set respectively

After calculating normalized correlation apply threshold criteria, in order to fond no change set. If the normalized correlation is less than 0.9 that means there cloud presents in subject image, so cloudy block of subject image is replace with the block set of reference image. If normalized correlation is greater than 0.9 therefore there is no cloud present in subject image, so there is no need to replace block of subject image with reference image. This process is repeated for all blocks.

c. No Change Set Normalization in Frequency Domain

In normalization procedure first reference image and subject is divided into block of size 8x8 pixels. A block of reference image is placed over block centered on the same coordinates in the other image. Then normalized correlation between two corresponding blocks is calculated by using frequency domain. This operation is repeated for all blocks. After this, we applied a threshold criterion, in order to select no change pixels used to find normalization coefficients. The correlation can be calculated as,

$$f(m,n) o w(m,n) = F^{-1}[F(u,v)W^*(u,v)] \quad (6)$$

where,

$f(m,n)$ is the block of 8x8 pixels of reference image

$w(m,n)$ is the block of 8x8 pixels of cloudy image

(m,n) are the special coordinates

$F(u,v)$ and $W(u,v)$] are the Fourier transform of $f(m,n)$ and $w(m,n)$ respectively.

* is the complex conjugate

o is the correlation

The Normalization correlation is derived from following equation,

$$NC = F^{-1}[F(u,v)W^*(u,v)] / max(F^{-1}[W(u,v)W^*(u,v)]) \quad (7)$$

The normalization coefficients can be obtained by,

$$ak = \frac{Syk^{(nc)}}{Sxk^{(nc)}}, b_k = \overline{y_k}^{(nc)} - a_k \overline{x_k}^{(nc)} \quad (8)$$

where, $\overline{x_k}^{(nc)}$ and , $\overline{y_k}^{(nc)}$ are the means. Sample variance and covariance for subset *NC* on two dates can be determined using equations

$$S^{(nc)} x_k x_k = \frac{1}{|NC|} \sum_{NC} (X_k - \bar{X}_K^{(NC)})^2 \text{ and} \quad (9)$$

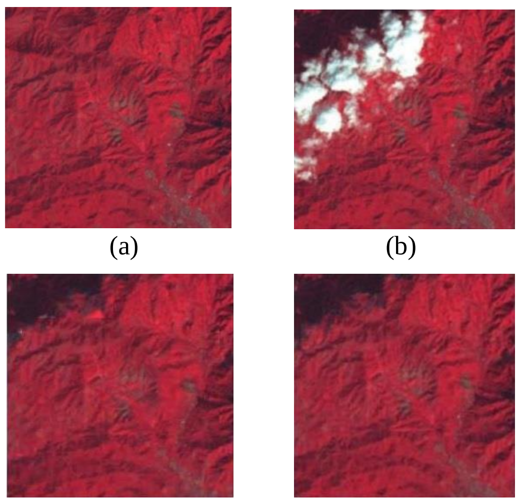
$$S^{(nc)} x_k y_k = \frac{1}{|NC|} \sum_{NC} (X_k - \bar{X}_K^{(NC)})^{1/2} (y_k - \bar{y}_K^{(NC)})^{1/2} \quad (10)$$

If the normalized correlation is greater than 0.9 then the block is assumed that it belong to no change set, that means there is no presence of cloud. If the normalized correlation is less than 0.9 then there is presence of cloud in subject image, in that case replace pixels set of subject image with the pixel set of reference image. This operation is repeated for all blocks. This procedures is repeated for all bands.

The visual appearance and histogram results are shown in Figure 5 and 6 respectively, the statistical results are given in table 1.

III. RESULT AND DISCUSSION

Comparing the visual appearance of the normalized process is the most strait forward way to judge the overall performance of this method. In doing so, both the normalized image and reference image are displayed side by side for special domain and frequency domain and visual closeness of the normalized image to the reference image is determined qualitatively. The visual appearance results are shown in Figure 5.



(a) (b) (c) (d)

Figure 5: Visual appearance observation: (a) reference image, (b) subject image, (c) normalized image in spatial domain, (d) normalized image in frequency domain The visual difference between normalized image and reference image is small, this implies that subject is radiometrically normalized. There is no observable difference in spatial domain frequency domain.

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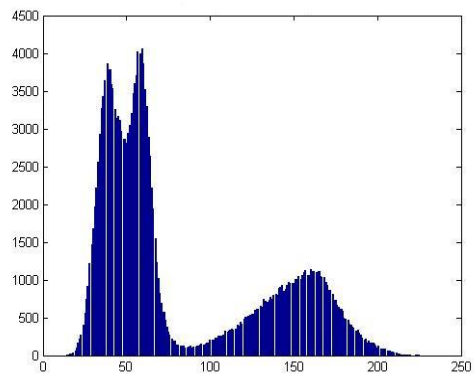
The root-mean-square error (RMSE) is used to measure the statistical agreement of the normalized image with the reference image, as follows:

$$RMSE_k = \sqrt{\frac{1}{|n|} \sum_n (s'_k - R_k)^2} \qquad (11)$$

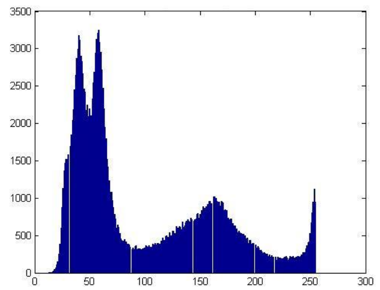
Where s'_k is radiometrically normalized digital no. in the subject image on date 1, R_k is the digital no. of reference image on date 2, and $|n|$ is the total no of pixels of the scene. Thus the digital no of the radiometrically normalized image are compare with those of the reference image. If the difference between these numbers is small the RMSE will be small. Result shows that obtained RMSE values are small. This implies that normalized subject image is radiometrically closer to the reference image. The results obtained for before and after normalization using spatial and frequency domain for RMSE values and entropy values are given below for different bands. The RMSE values obtained after normalization are small as compared to before normalization for both spatial domain and frequency domain. Therefore the normalized image is very closer to reference image that is clouds are successfully removed here. The entropy values of reference image and normalized image are closer that also implies that the normalized image is similar to reference image.

Table 1: Statistical results before and after normalization

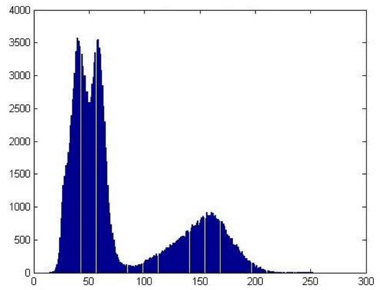
Band	Before Normalization			After Normalization			
	RMSE	Entropy		Spatial Domain		Frequency Domain	
		REF IMG	CLD IMG	RMSE	Entropy	RMSE	Entropy
Band1	22.1222	2.2472	2.4482	12.1040	2.0845	1.4907	2.0360
Band2	18.1488	6.0444	4.1639	17.9746	5.6125	12.5111	5.4984
Band3	12.8927	6.2879	6.4469	12.7717	6.3385	12.8995	6.3239
Band4	11.1638	6.3758	6.5077	12.5020	6.3811	11.3228	6.3540
VRB	11.8710	5.1153	6.4723	8.2953	5.1334	6.9920	5.1371
NIR	8.5548	6.6890	7.3127	7.8148	6.9653	8.4403	6.9438



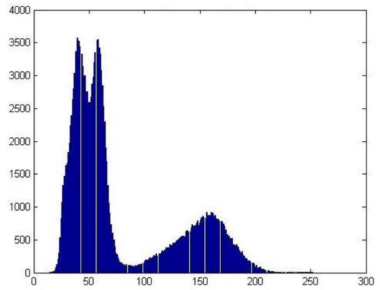
(a)



(b)



(c)



(d)

Figure 6: Histogram of (a) reference image, (b) subject image, (c) normalized image in spatial domain, (d) normalized image in frequency domain.

In the histogram of subject image bright information is more because of cloudy pixels. These pixels are successfully removed after normalization using no change set normalization technique, so histogram of normalized image looks similar to reference image.

IV. CONCLUSION AND FUTURE SCOPE

The average brightness threshold algorithm successfully detects the cloud from cloudy image, for that purpose proper cutoff value (threshold value) is chosen that separates the cloudy and unclouded regions. If the average brightness level is low then cutoff value is very much above the average brightness and if the average brightness level is high then cutoff value is marginally above the average brightness value. Here the relative radiometric normalization technique using no change is proposed for cloud removal. The subject image block set is compared with the block set of reference image, by selecting the proper threshold the cloudy block sets from subject image are removed. The quality of radiometric normalization is statistically assessed by Root Mean Square Error, which is small here.

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The proposed scheme successfully normalized cloudy subject image by using spatial domain and frequency domain so that normalized image looks similar to reference image after normalization. In the visual appearance there is no observable difference in spatial domain normalized image and frequency domain normalized image. In statistical agreement the RMSE values of frequency domain are slightly smaller than the spatial domain values. That is statistical results of frequency domain better than spatial domain. The entropy is also calculated, the entropy of reference image and normalized image is closer as compared to cloudy image that is normalized image is similar to the reference image which implies that subject image is radiometrically normalized.

A. Future Scope

In no change set normalization method, the detected cloud is removed and replaced with data from another image of the same area that is to normalized the subject image reference image is must and care should be taken for selection of reference image. Instead of this, the pixels in cloud area can be replaced with estimated pixel values obtained from regression of same image.

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