Radiometric Normalization of Satellite Images using Ordinal Conversion

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ABSTRACT

Radiometric normalization of multi-temporal satellite image is very important for change detection or image mosaic. To obtain land cover changes to reduce the false changes, it is necessary to perform radiometric normalization of multi-temporal satellite images. There are two types of methods: absolutely radiometric normalization (ARN) and relative radiometric normalization (RRN). ARN converts digital number (DN) of each image into land-surface reflectivity directly. It required many synchronous observation data of satellite to revise atmospheric condition and sensor response. But it is difficult, expensive and unpractical to obtain such data. An alternative to absolute radiometric correction is relative correction (RRN) which is commonly used. Various methods are there for radiometric correction like MAD, IR-MAD, Histogram matching (HM), Simple Regression (SR), Dark and bright set (DB). A method called ordinal conversion which neither belongs to ARN nor RRN for radiometric normalization and change detection. In this paper Ordinal conversion method is compared with histogram matching method and experimental results are discussed.

Keywords: Radiometric normalization, Ordinal conversion,Histogram-matching.

1. INTRODUCTION

Remote sensing can be broadly defined as the collection and interpretation of information about an object, area, or event without being in physical contact with the object. Aircraft and satellites are the common platforms for remote sensing of the earth and its natural resources. Aerial photography in the visible portion of the electromagnetic wavelength was the original form of remote sensing but technological developments has enabled the acquisition of information at other wavelengths including near infrared, thermal infrared and microwave. Collection of information over a large numbers of wavelength bands is referred to as multispectral data. The development and deployment of manned and unmanned satellites has enhanced the collection of remotely sensed data and offers an inexpensive way to obtain information over large areas. The capacity of remote sensing to identify and monitor land surfaces and environmental conditions has expanded greatly over the last few years and remotely sensed data will be an essential tool in natural resource management. It is the science of deriving information about the earth's land and water areas from images acquired at a distance. “Radiometric Correction” is defined as the correction of variation in data values that is caused by sensor malfunctions and atmospheric conditions and techniques that correct and improve radiometric values of individual pixels is called as Radiometric Enhancement.

Radiometric correction of remotely sensed data normally involves the processing of digital images to improve the fidelity of the brightness value magnitudes. To obtain land cover changes to reduce the false changes, it is necessary to perform radiometric normalization of multi-temporal satellite images. There are two types of methods: absolutely radiometric normalization (ARN) and relative radiometric normalization (RRN). ARN converts digital number (DN) of each image into land-surface reflectivity directly. It required many synchronous observation data of satellite to revise atmospheric condition and sensor response. But it is difficult, expensive and unpractical to obtain such data. An alternative to absolute radiometric correction is relative “correction,” which is commonly used in one of two ways: adjusting individual bands of data within a single image (i.e., based on subtracting dark object values from each band) or normalizing bands in images of multiple dates relative to a reference image. The primary difference to note between the two general approaches to relative normalization is that a master image is selected in studies involving multiple images of the same area. RRN use one reference image, then normalize the DN of multi-temporal images as a reference band by band and then convert image into the same radiometric scale. This avoids the complicated computation of converting DN of each image to radiation.

RRN is developed based on the assumption that there is a linear relationship among the DN of the same band of multi-temporal images in the same area [1, 2]. A variety of RRN methods are available now, These methods include pseudo-invariant features (PIF) [2], dark and bright set (DB) [3], histogram matching (HM) [4], automatic scattergram-controlled regression (ASCR) [5],Multivariate alteration detection transformation (MAD) [6], iteratively reweighted MAD transformation (IR-MAD) [7]. Ding Yuan applied seven empirical multitemporal radiometric normalization techniques to 1973 and 1990 Landsat MSS images acquired of the Washington D.C. area. The results from the various techniques have been compared both visually and using measure of the fit based on standard error statistic. Schott et al presented pseudo-invariant feature normalization which analyzed the elements whose reflection distribution has statistical invariance ,such as concrete ,asphalt and roottops those elements are assumed not to have any significant change between two acquisition dates. Difference in gray level distribution of these invariant objects are supposed to be linear and are corrected statistically to perform the normalization [2]. Elvidge et al developed a radiometric normalization method (no change pixel set) through a no change set determined from the scattergram between near infrared bands of the subject. Pixels no- change region will be used to compute normalization coefficients for all bands[5].

2. PROPOSED METHOD

In this study, we use ordinal conversion to normalize multi-temporal images and compare it with histogram matching method to examine if ordinal conversion is a more effective and appropriate radiometric normalization method for multi-temporal satellite images.

2.1 Histogram matching

Histogram Matching method is used to match the histogram of one displayed image to another displayed image. We can use this feature on both grayscale and color images. It uses the reference image histogram to modify the subject image histogram in order to make the subject image histogram distribution similar to the reference image histogram distribution Many researchers applied histogram matching to normalize the radiometric differences between the satellite images acquired at different times and by different sensors to monitoring land use and land cover changes[8].

Data sets I:

In this experiment two temporal images were used for radiometric normalization. One image was acquired on August 8, 2004. The other one was acquired on August 29, 2008. For convenience, the two images are called image 2004 and image 2008 respectively. Compared to image 2008, image 2004 has a duller appearance, with less contrast than image 2008. Therefore, image 2008 is selected as the reference image in the histogram matching method.

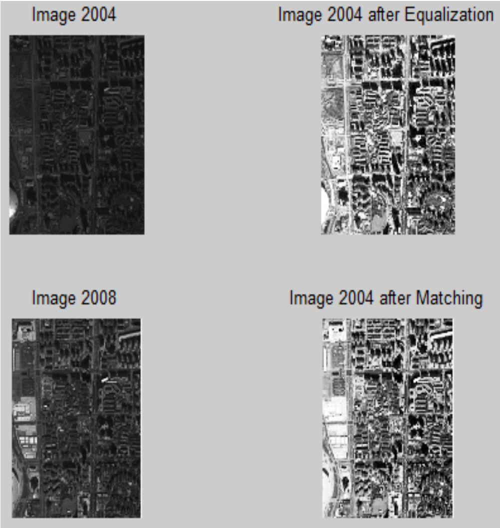

Fig 2.1(a): Image 2004 processed by histogram matching

Fig 2.1(b): Image 2008 processed by histogram matching

Data sets II:

In the second experiment again two temporal images were used for radiometric normalization. One image was acquired on April , 2001. The other one was acquired on February, 2002. For convenience, the two images are called image 2001 and image 2002 respectively. Compared to image 2002, image 2001 has a duller appearance, with less contrast than image 2002. Therefore, image 2002 is selected as the reference image in the histogram matching method.

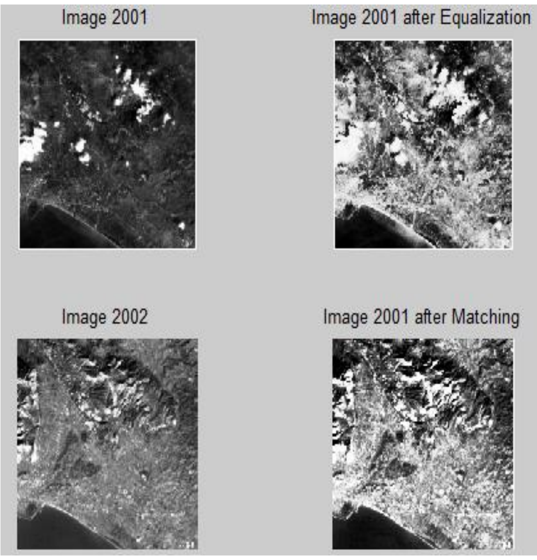

Figure2.1(c): Image 2001 processed by histogram matching

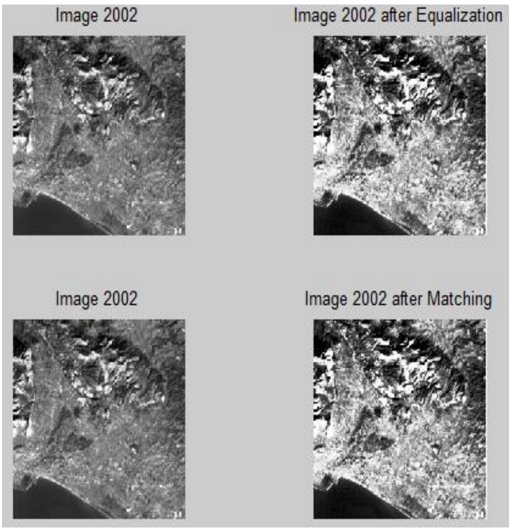

Figure2.1(d): Image 2002 processed by histogram matching

2.2 Ordinal conversion

Nelson introduced a method called ordinal conversion which neither belongs to ARN nor RRN for radiometric normalization and change detection[8]. This method does not require the conversion of the digital number (DN) of each image into land-surface reflectivity directly, and it does not need a reference image. It converts image values to ordinal ranks. When image pairs are converted to ordinal ranks, the global characteristics of the distributions of pixel values are matched. Thus ordinal conversion may be a useful technique for normalizing multi-temporal high resolution imagery. In this study, we use ordinal conversion to normalize multi-temporal images and compare it with histogram matching method to examine if ordinal conversion is a more effective and appropriate radiometric normalization method for multi-temporal satellite images. This approach involves three main steps: (1) extracting pixel values from image pairs, (2) sorting original pixel values of image pairs in ascending order, and (3) assigning each pixel a new value based on its reflectance value relative to all other pixels. When image pairs are converted to ordinal ranks, the global characteristics of the distributions of pixel values are matched[4].

Data sets I:

In this experiment also two temporal images were used for radiometric normalization, image2004 and image2008. For processing of images, ordinal conversion method does not need reference image.

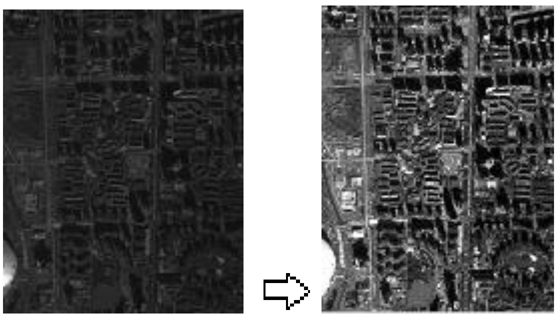

Figure 2.2(a): Image2004 processed by ordinal conversion

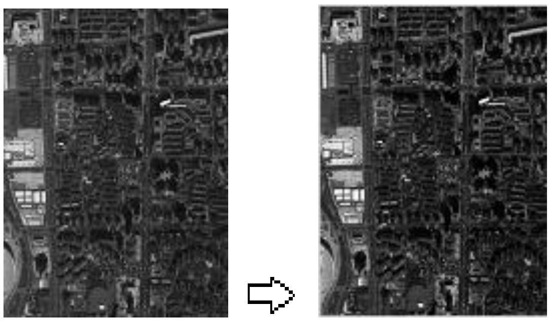

Figure 2.2(b): Image2008 processed by ordinal conversion

Data sets II:

In this experiment, for ordinal conversion method no need to take reference image. Image 2001 and Image 2002 processed independently.

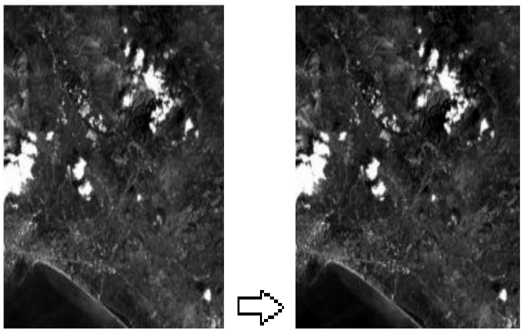

Figure 2.2(c): Image 2001 processed by ordinal conversion

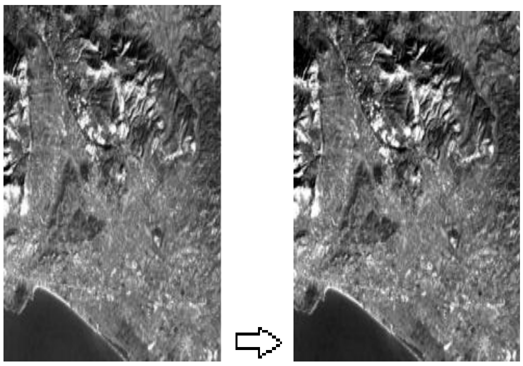

Figure 2.2(d): Image 2002 processed by ordinal conversion

3. RESULTS AND DISCUSSION

(i) Entropy: Entropy defines the average information content in image. For grey image it should be close to 8. Entropy is directly proportional to image quality.

$$\text{Entropy} = -\sum_{i=1}^{n} Pi \log Pi$$

In the above expression, P_i is the probability that the difference between 2 adjacent pixels is equal to i, and Log_2 is the base 2 logarithm.

(ii) Standard Deviation:

In statistics and probabilitytheory, standard deviation (represented by the symbol sigma, **σ**) shows how much variation or dispersion exists from the average (mean), or expected value. A low standard deviation indicates that the data points tend to be very close to the mean; high standard deviation indicates that the data points are spread out over a large range of values.

Let X be a random variable with mean value μ:

$E[X] = \mu$

Here the operator E denotes the average or expected value of X.

$$\sigma = \sqrt{E[(X-\mu)2]} = \sqrt{E[X2] + E[(-2\mu X)] + E[\mu 2]}$$

$$= \sqrt{E[X2] - 2\mu E[X] + \mu 2}$$

$$= \sqrt{E[X2] - 2\mu 2 + \mu 2} = \sqrt{E[X2\} - \mu 2}$$

$$= \sqrt{E[X2] - (E[X])2}$$

(iii) Relative Mean:

The mean value of pixels in a band is the central value of the distribution pixel in that band. The relative shift in the mean value quantifies the changes in the mean of the image due to processing.The relative shift in mean is defined as:

$$\text{Relative Mean} = \frac{(\text{output mean} - \text{original mean})}{\text{original mean}} * 100$$

A positive value relative mean indicates a shift towards white and negative value indicates shift towards gray.

These parameters has been calculated for the image taken in Data sets I and Data sets II and their values are shown in the table respectively.

Table3.1: Results for Data sets I

Methods →	Histogram Matching		Ordinal Conversion	
Parameter ↓	Image 2004	Image 2008	Image 2004	Image 2008
Entropy	5.3894	5.9552	5.6265	6.8319
Standard Deviation	74.8419	74.8295	51.1236	45.3842
Relative Mean	2.44	1.00	1.03	- 0.13

Table3.2: Results for Data sets II

Methods →	Histogram Matching		Ordinal Conversion	
Parameters ↓	Image 2001	Image 2002	Image 2001	Image 2002
Entropy	5.8437	5.9606	6.7190	7.3729
Standard Deviation	74.9243	74.8142	57.8899	50.3682
Relative Mean	0.97	0.19	- 0.08	- 0.05

4. CONCLUSION

Experimental results from this study suggest that the ordinal conversion method is more effective than histogram matching method when both methods are applied to multi-temporal satellite images. Thus ordinal conversion is a more appropriate radiometric normalization method for multi-temporal high resolution satellite images.

5. REFERENCES

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