EVALUATING EFFECTIVENESS OF RADIOMETRIC CORRECTION FOR OPTICAL SATELLITE IMAGE USING STATISTICAL PARAMETERS

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ABSTRACT

Optical satellite image (OSI) in original form (raw image) is an image of optical gray values of each pixel, characterized by DN quantity (Digital Number). DN values not only contain the signal reflected directly from the surface of the object but also contain other diffusing and reflecting signals in atmospheric environment. In many practical applications image data in the form of the original DN image can not use directly, but need to filter the noise signals and then convert it into image reflected of objects in the ground surface.

In order to increase the accuracy and reliability of products created from satellite images such as image classification, change detection of land use/land cover etc., the processing of radiometric corrections from DN (raw) image into reflected image in ground surface have to be done. The present article uses statistical parameters of digital image calculated before and after radiometric corrections to compare and evaluate its quality.

1. INTRODUCTION

Analyzing satellite image have an important role in monitoring and modeling environmental problems. Repeated observation of a given area over time yields potential for many forms of change detection analysis. These repeated observations are confounded in terms of radiometric consistency due to changes in sensor calibration over time, differences in illumination, observation angles and variation in atmospheric effects. Radiometric correction of satellite image data comprises of two issues: absolute and relative correction (*Seema and Udhav, 2010*). Absolute radiometric correction converts the digital number of a pixel to a percentage reflectance value using established transformation equations (*Chavez and Mackinnon, 1994; Caselles and Garcia, 1989*). Relative radiometric correction normalizes multiple satellite scenes to each other. Most forms of absolute radiometric correction rely on sensor calibration coefficients, atmospheric correction algorithms, and illumination and observation geometry coefficients. These data are used in a radiative transfer model to correct the imagery. Relative radiometric correction has several advantages over absolute radiometric correction. The methodology is usually simpler, requires less computer operating time and less theoretical understanding (*Hall, et al., 1991; Schott, et al., 1988*).

Our purpose of this study describes how to calculate the reflectance at surface and reflectance at the top of atmosphere by certain algorithms and assess data accuracy after calculating.

2. BACKGROUND

The sun's rays carry energy with five different routes, finally going on the satellite's sensor. Figure 1 illustrates the paths of the sun's rays with the characteristic quantities back to sensor (*Jesen, 1996*).

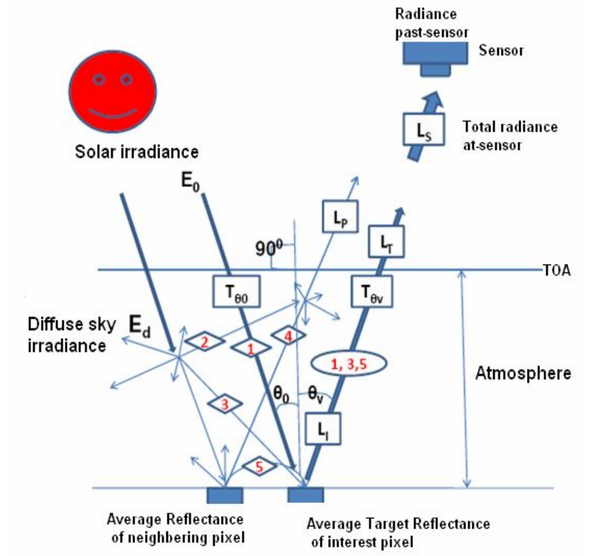


Figure 1. The paths of sun's rays on the sensor.

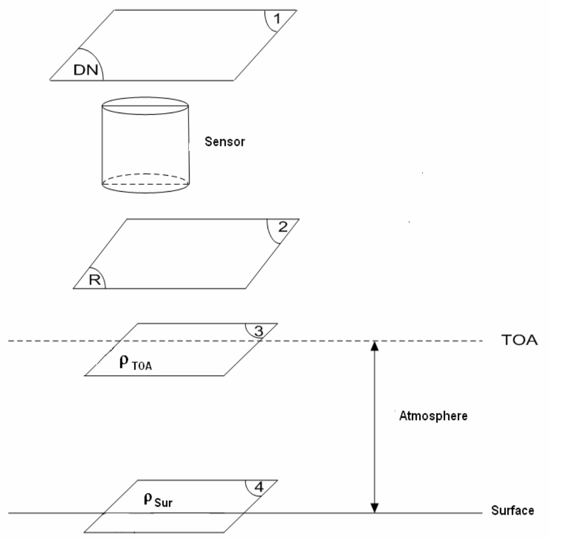


Figure 2. The process of transformation from DN image → R → ρ_{TOA} **→** ρ_{sur} **.**

Figure 1 clearly shows the DN values (Digital Number) of the scene with signal L which were recorded by sensor will be the sum of "real" signal, Ls (direct reflection from objects on ground surface to sensor) and the "noise" signal, Lp (the reflection, scattering by the surrounding environment).

$$L = Ls + Lp \qquad (1)$$

The nature of the problem of radiometric correction of satellite image is to remove the noise signal Lp. Assuming that the topography surface is Lambert surface (smooth surface, height difference not significant), the radiometric correction should be done are:

- Correction of spectrum sensor based on its calibrated parameters;
- Atmosphere correction.

Relationship between radiance spectrum of the four image positions in the space of the same area is described in Figure 2. Four image positions are as follows:

- Image No.1 is the original (raw) image with pixel DN values (past-sensor image).
- Image No.2 is the result of sensor's spectrum correction; actually converting DN image (past-sensor image) into the radiance image R (at-sensor image).
- Image No.3 is the conversion result of radiance image R into reflected image at the top of atmosphere, (denote ρ_{TOA} image).

- Image No.4 is the result of continuing a conversion of ρ_{TOA} image into the reflected image of the surface topography (denote ρ_{SUR} image).

3. EXPERIMENTAL PART

3.1 Image data

Input Data is a satellite image Landsat ETM^+ taken on 29/9/2001 of Cam Pha - Quang Ninh areas (Figure 2). Image parameters of useful Landsat scene in Cam Pha are presented in Table 1.

Table 1. Scene of Landsat ETM^+ satellite image of Cam Pha area

Parameters of Landsat ETM^+ image				
Acquisition date	29/09/2001			
Datum grid	UTM			
Solar angle (degree)	56.2178576			
	band 1	band 2	band 3	band 4
Radiance values Lmax (W/m^2*ster*μm)	191.60	196.50	152.90	241.10
Radiance values Lmin (W/m^2*ster*μm)	-6.200	-6.400	-5.00	-5.100
Sun radiance value (W/m^2*μm)	1969.00	1840.00	1551.00	1044.00

Experimental part has been conducted according to scheme in Figure 2. Two products of image category also have been created:

- True color (RBG) combined images;
- NDVI vegetation index images.

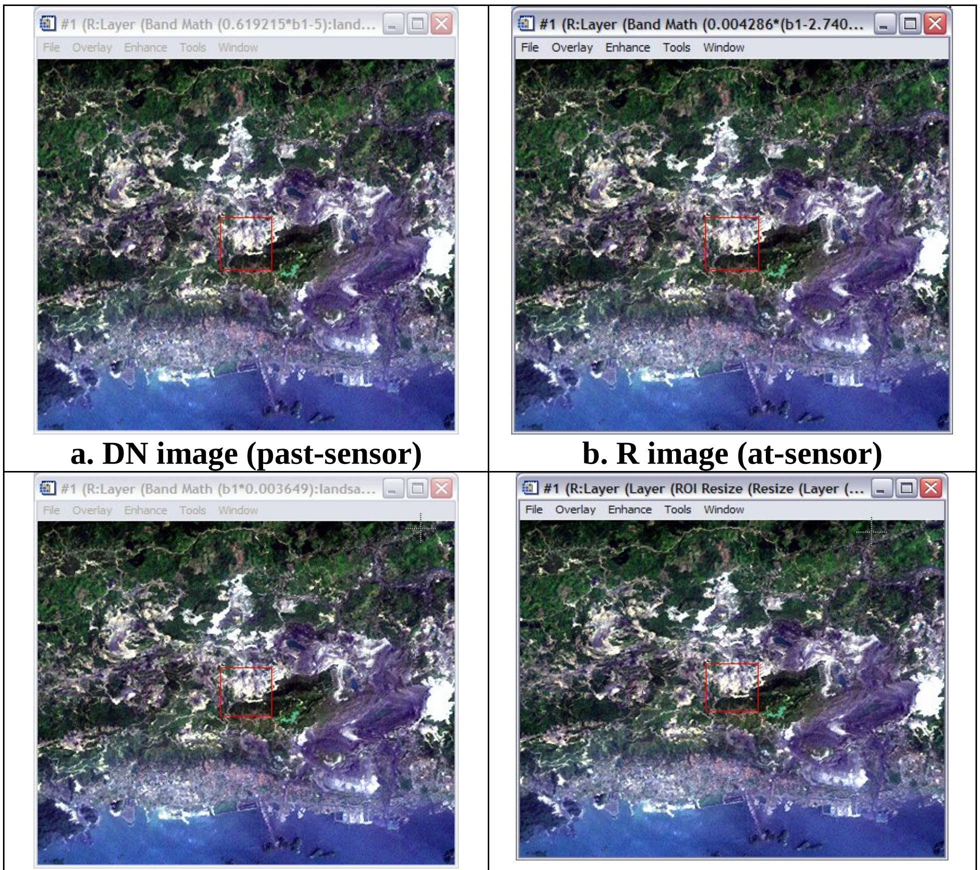
3.2 Products of true color (RBG) combined image

The number of color combined images are four images corresponding to the four positions in space as introduced in Figure 2. Creating the image sequence is described as written in paragraph 2.

Output four color combined images corresponding to the four image positions in space as DN (1), R (2) (Radiance), ρ_{TOA} (3), ρ_{sur} (4) image is shown in Figure 3.

The statistical parameter values of the four RBG color combined image were calculated and recorded in Table 2; where "Mean" is the average value of images (image's mathematical expectation); "Var" is image variance and CV is image's change variance index of image, calculated by the formula.

$$\left(CV = \left|\sqrt{\mathrm{var}} / Mean\right|\right) \qquad (2)$$



a. DN image (past-sensor) **b. R image (at-sensor)**

c. ρ_{TOA} image (at TOA) **d. ρ_{SUR} image (in surface)**

Figure 3. Four color combinations of images

Table 2. Statistical parameters of four color RBG combined

Statistical Parameters	**DN (1)**	**R (2)**	ρ_{TOA} **(3)**	ρ_{sur} **(4)**
Mean	74.5	53.339125	0.0363000625	0.243616
Var	107.316625	67.944025	0.000416695625	0.001053128
CV	0.13905	0.154536	0.56234	0.133209

Through Figure 3 and Table 2 show: Although observed with eye we hardly detect the difference between images (1), (2), (3) and (4), but the quantitative values in Table 1 reflects the nature of these images very different. We have commented:

- DN image or past-sensor image with No (1) has CV smaller than 1 but have largest variance with respect to others.
- At-sensor image or radiance image, R, with No (2) (after correcting sensor spectrum) has CV approximate to CV of DN image (1), but its variance is nearly two times smaller than variance of DN image (1).
- Image at the top of atmosphere, ρ_{Sur}, with No (3) has CV larger than CV of DN (1), but still smaller than 1. Its variance is very small (considered equal to 0).
- The reflected image on the topography surface, (ρ_{Sur}), with No (4) has CV approximately equal to CV of DN image (1), but its variance value, Var, is 100 thousand times smaller than DN image (1).

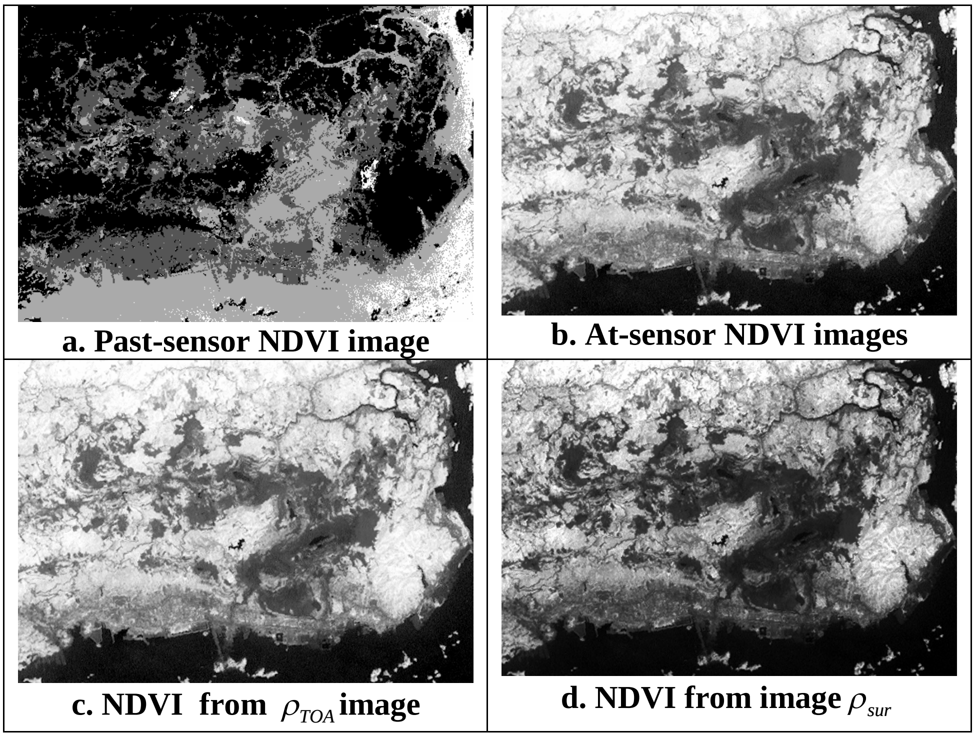
Clearly, reflected image on the topography surface with ρ_{Sur} (4) has the highest quality. From evaluating of color (RBG) combined image, we concluded that by “feeling” in the computer screen, our eyes may misunderstand the combination of color images without a difference, but with statistical models of image, we see the nature of this type of images completely different in quality.

3.3. Products of NDVI vegetation index image

Going deeply in detail, we use images of vegetation index (VI) to analyze four types of image such as DN, R, ρ_{TOA}, and ρ_{SUR}. Usually images of vegetation use only NDVI defined as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED} \qquad (3)$$

We have four types of vegetation index NDVI images such as (DN), NDVI (R), NDVI (ρ_{TOA}) and NDVI (ρ_{SUR}) that corresponding to 4 position in space (see Figure 2). It means vegetation index images were created by pixel DN values, (past-sensor); R (at-sensor image); reflected image at the top of atmosphere, ρ_{TOA} and reflected image in the topography surface, ρ_{SUR}**,** respectively. Four DNVI images are shown in Figure 4.



a. Past-sensor NDVI image

b. At-sensor NDVI images

c. NDVI from ρ_{TOA} image

d. NDVI from image ρ_{sur}

Figure 4. Four NDVI images

The statistical parameter values of the four NDVI images were calculated and recorded in Table 3 (see footnote of Table 2).

Table 3. Statistical parameters of four NDVI images

Parameters	NDVI (DN)	NDVI (R)	NDVI (ρ_{TOA})	NDVI (ρ_{sur})
Mean	0.25	0.1552877775	0.33104825	-0.99847675
Var	10.9221465	0.04456275	0.037273225	0.0000004307545
CV	13.21947	1.359404	0.583186	0.00065732

Deeply analysis based on vegetation index images we see, by a "feeling" of the human eye; we can recognize the difference between the NDVI images. By "quantitative values" through image statistical parameters in Table 3, as confirmed differences in the nature of the four types of NDVI images. NDVI images (ρ_{sur}) is regarded as the variance of 0 with CV variable is the smallest. This is the image of the highest quality. There should also be added that the value of "Mean" of NDVI (ρ_{sur}) approximately equal to -1 because this area is coal mining, the vegetation factor is very low. Value "Mean" of the image NDVI (DN) is the "virtual" value because the value of "Var" and the variable CV are very large compared to other images. In fact, using NDVI (DN) to classify images in research of land cover/land use change, as well as in some other tasks will have very low reliability.

In short, radiometric correction for Lambert terrain from DN to image reflected image in the topography surface is needed to practical applications in the thematic maps of monitoring resources and environment in order to increase the accuracies and reliabilities of useful products.

4. REFERENCES

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