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A PROCEDURE FOR TESTING THE QUALITY OF LANDSAT ATMOSPHERIC CORRECTION ALGORITHMS

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14. Abstract/Notes

There are two basic methods for testing the quality of an algorithm to minimize atmospheric effects on LANDSAT imagery: a)test the results a posteriori, using ground truth or control points, b)use a method based on image data plus estimation of additional ground and/or atmospheric parameters. This paper suggests a procedure based on the second method. In order to select the parameters, initially the image contrast is examined for a series of parameter combinations. The contrast improves for better corrections. In addition the correlation coefficient between two subimages, taken at different times, of the same scene is used for parameters' selection. The regions to be correlated should not have changed considerably in time. A few examples using this proposed procedure are presented.

15. Remarks

This paper will be presented at the Remote Sensing Symposium to be held at the University of Liverpool, Liverpool, England.

A PROCEDURE FOR TESTING THE QUALITY OF LANDSAT ATMOSPHERIC CORRECTION ALGORITHMS

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Abstract: There are two basic methods for testing the quality of an algorithm to minimize atmospheric effects on LANDSAT imagery: a) test the results a posteriori, using ground truth or control points, b) use a method based on image data plus estimation of additional ground and/or atmospheric parameters. This paper suggests a procedure based on the second method. In order to select the parameters, initially the image contrast is examined for a series of parameter combinations. The contrast improves for better corrections. In addition the correlation coefficient between two subimages, taken at different times, of the same scene is used for paramters' selection. The regions to be correlated should not have changed considerably in time. A few examples using this proposed procedure are presented.

1. INTRODUCTION

The presence of the terrestrial atmospheric presents a problem to classify satellite images, because it tends to blur the original scene. In order to minimize this effect, it is possible to simulate the atmospheric influence on the satellite image, by means of a computer program, and subtract it from the original digitized scene.

Turner and Spencer (1972), O'Neil et al. (1978) have developed some methods to minimize the effect of the atmosphere. Due to the need of having such a system at INPE, a model based on O'Neil's method was selected. This method underwent extensive modifications in order to better suit our atmospheric conditions, and to become faster and interactive, besides producing graphic outputs (Dias et al., 1981; Vijaykumar and Dias, 1982).

It is important to test quantitatively the quality of the atmospheric correction models, in order to improve the image classification. This paper suggests a procedure to select a better correction in specific conditions.

2. SUGGESTED METHOD

Due to the high cost and associated delays in obtainning ground truth and/or control points the suggested method uses, as inputs, only image data plus some estimated parameters. The estimated parameters are known to belong to well accepted intervals. They can be changed on these intervals. As output, the image contrast and correlation coefficient of two time spaced images are analysed.

INPE's correction algorithm is composed at two parts. Initially, based on image data an atmospheric transmittance program is used to calculate the total transmittance (aerosol and molecular scattering). It uses the LOWTRAN 4 packets. These packets are well known (Selby et al., 1978), but were modified in order to become faster interactive, user-friendly and with optional graphic output. The input parameters are: a) atmospheric model (standard US, midlatitude summer, midlatitude minter, tropical, user-defided, b) visibility (0 to 23 km), c) altitude at ground level, d) initial frquency (for LANDSAT channels), e) final frequency (for LANDSAT channels), and f) channel width. Optionally, radiosonde data can be entered as a new atmospheric model.

All parameters one obtained without ground truth except the visibility and the model that may be estimated based on image data, and latitude (for example, midlatitude summer model, visibility = 15 km). An alternative is the use of radiosonde data to determine the atmospheric model (a very useful and recommended procedure when data is available). Unfortunately this type of data is not always available, for Brazilian images.

The second part is the procedure itself, it uses a program on the GE Image-100 (Multispectral Image Analyzer attached to a PDP-11/45) to treat the digitized image directly. This interactive program called ATMCOR is very fast (about 10 seconds for the controle image of 512 x 512 pixels), and even faster for a correction on a cursor in a small subimage. The inputs are: a) Landsat channel, b) ground albedo, c) solar zenith angle, d) aerosol optical depth, and e) transmittance. ATMCOR calculates the radiance path based on O'Neil et al. (1978) tables with a spline interpolation for zenith angles, and aerosol optical depths.

The input parameters that have some uncertainties are the albedo and the aerosol optical depth. The proposed procedure is the following: a) get an image from a desired scene; b) correct it with estimated aerosol optical depth and albedo; c) check the image contrast for selected points; d) repeat the procedure with new input data; e) check the new image contrast for the same selected points comparing it with the result on item c; f) repeat c to e until the contrast has reached a maximum. The idea is that a sharp contrast is obtained when the atmospheric effect is minimized, for the atmosphere tends to blur an image, thus reducing its contrast.

Care should be taken, for a sharp contrast alone is not by itself sufficient. A second criterion is then employed to decide which correction is best suited for the prevailing conditions. Using two images of the same scene, separated on time, the correlation coefficient between two selected subimages are obtained. A good correction (near 1) between two different atmospheric corrected subimages, that did not change in time, suggests that the atmospheric effect is minimum and the correction adequate. On the other hand, a poor correlation (near zero) indicates a strong atmospheric interference (correction model not suitable) or a poorly chosen subimage. Of course, the subimages to be correlated must be chosen such that no change with time have occurred in them. For example, a crop on different stages is not acceptable, but an airport runway is an excelletn choice.

3. EXPERIMENTAL RESULTS

In order to test the suggested model it was chosen a Paraîba Valley scene (orbit 150, point 28) of the Landsat satellite. Two images widely spaced on time were selected; July, 11th, 1973 and January, 31st, 1978, with a cloud cover at less than 10%. Table 1 indicates the image data.

The transmittance for both images was calculated by LOWTRAN 4, using midlatitude/winter for ≠ 1, and midlatitude/summer for ≠ 2. The visibility was estimated at 15 km. Table 2 shows the computed transmittances.

Initially the contrast is studied. It is defined for this work purposes as

$$C = \frac{|I_t - I_m|}{I_m}$$

where I_t is the maximum value in the target pixel area, and I_m, the maximum pixel value in the neighbourhood. The image ≠ 2 was selected, and the chosen points were: a) Airport at São José dos Campos, A; b) Forest area in São José dos Campos County, F; c) City of Taubaté, T; and d) water reservoir in Jacareí County, J. The scale used was 1:250,000 for contrast studies. In this case, channels 4, 5 and 7 were used, and the albedo was estimated at 0.2. The target area was 4 x 4 pixels. The neighbourhood was 32 x 32 pixels around the target area.

On Table 3 the contrasts for the corrected images in the four target areas in the three selected channels are shown, as well as the contrasts in the original images.

It should be noted that the high contrast on the original images is due to the fact that the atmospheric correction tends to increase all pixel values, thus giving an apparent high contrast to the original scene. For comparisson only the three corrected images (0.12, 0.24 and 0.36 aerosol optical depth) should be considered. At the areas A (Airport), and T (Taubaté) the aerosol should be 0.24. On the forest area, F, it should be 0.36, and at the Jacareí water reservoir, J, it is undecided, since for each channel there is a different result. The results are the expected ones, since it was reasonable to have a higher aerosol optical depth due to a large aerosol concentration on the atmosphere over a forest at this time of the year than over a city (T) or over an airport (A).

As far as the correlation coefficients were considered, the channels 5 and 7 using target areas of 16 x 16 pixels were used. The four target areas are shown on Table 4.

The images for 1973 and 1978 were registered nanually before the tests.

Making all possible combinations, it was noted that area ≠ 1 (Oil refinery) was poorly correlated on channels 5 and 7 for all at them. This result was expected, and this area was included for testing the method. The subimages should be poorly correlated because in 1973 the oil refinery area was a pasture, with complets different spectral characteristics. The highest correlation coefficient was obtained for aerosol optical depth, A_d, equal to 0.12 on both images.

Area ≠ 2 (city at Jacareí) presented the highest correlation coefficient, for channels 5 and 7, at 0.315 and 0.454 respectively. This corresponds on channel 5 to A_d = 0.24 on both images. This area is not very suitable for this kind of test, because in five years the area of 16 x 16 pixels chosen changed a lot.

Another area that should present some problems is area ≠ 4 (forest area in São José dos Campos County). The two subimages are five years apart and one is for winter and the other is for summer. It was expected that the correlation coefficient would be smaller than for area ≠ 2, but higher than for area ≠ 3, and indeed it occurred. The actual results were, for channels 5 and 7, respectively, 0.123, and 0.172, the A_d's for channel 5 were 0.12 x 0.12, while for channel 7 were, 0.36 x 0.36.

The airport (area ≠ 3) was expected to yield the larger coefficient of correlation. Indeed, the results are the following: Channel 5, A_d's 0.24 x 0.24, correlation coefficient = 0.946; Channel 7, A_d's 0.12 x 0.12 and 0.12 x 0.36, correlation coefficient = 0.534.

4. CONCLUSIONS

Summing up the data above, it is possible to suggest that according to contrast studies and correlation coefficients, the best results for the A'_ds are the ones shown on Table 5, below.

From Table 5 it is seen that the best correction for the airport area should be with A_d = 0.24 and for the forest area A_d = 0.36. It should be pointed out that the correlation results for the forest area should be taken with reserve, due to the fact that the two subimages are five years apart and are for different seasons.

The inclusion of areas like the oil refinery, water reservoir, Taubaté city and Jacareí city had the purpose of checking the behevior of the suggested procedure.

The results and conclusions here presented are far from complete, and much more study and effort should be employed in the future, the aim of this work being to show that it is possible, in principle, to test quantitatively the atmospheric correction models based only on image data, and the estimation of parameters within a well defined range. Of course, it was possible to have other parameters changed, such as the albedo and even the transmittance. This has not been done yet, but is planned for the near future.

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TABLE 1 - IMAGE DATA

ID	PLACE	DATA	ORBIT/ POINT	SOLAR ZENITH ANGLE	SCALE	CLOUD COVER	ESTIMATED ALBEDO	LATITUDE
1	Paraiba Valley, Brazil (Winter)	11 JUL 73	150.28	60^{o}	1:100,000	10%	0.2	23.5
2	Paraiba Valley, Brazil (Summer)	31 JAN 78	150.28	50^{o}	{1:100,000 and 1:250,000}	0%	0.2	23.5

TABLE 2 - TRANSMITTANCE

ID	Ch. 4	Ch. 5	Ch. 6	Ch. 7
1	0.5284	0.6087	0.6333	0.7092
2	0.7376	0.8007	0.7946	0.8064

TABLE 3 - CONTRASTS

Aerosol Optical Depth, A_d	A			F			T			J		
	4	5	7	4	5	7	4	5	7	4	5	7
0.12	0.528	0.441	0.456	0.250	0.370	0.550	0.323	0.333	0.416	0.189	0.227	0.833
0.24	0.526	0.496	0.459	0.323	0.357	0.551	0.333	0.337	0.422	0.179	0.217	0.894
0.36	0.533	0.489	0.458	0.342	0.406	0.554	0.325	0.329	0.420	0.186	0.240	0.857
ORIGINAL	0.535	0.495	0.466	0.357	0.400	0.561	0.333	0.333	0.426	0.187	0.250	0.937

TABLE 4 - CORRELATED AREAS

ID	CHANNELS	AEROSOL OPTICAL DEPTHS	DESCRIPTION
1	5,7	ORIG, 0.12, 0.24, 0.36	Oil refinery (did not exist in 1973
2	5,7	ORIG, 0.12, 0.24, 0.36	City of Jacareī
3	5,7	ORIG, 0.12, 0.24, 0.36	Airport of São José dos Campos
4	5,7	ORIG, 0.12, 0.24, 0.36	Forest area in São José dos Campos County

TABLE 5. Best A_d (1978 image)

Channel	Airport		Area	
	(corr. coef.)	(contrast)	(corr. coef.)	(contrast)
4	-	0.36	-	0.36
5	0.24 x 0.24	0.24	0.12 x 0.12	0.36
7	0.12 x 0.36	0.24	0.36 x 0.36	0.36