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EFFECT OF THE ATMOSPHERE ON THE CLASSIFICATION OF LANDSAT DATA

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ABSTRACT

The purpose of this work was to develop a suitable computer program to correct computer compatible tapes, obtained from LANDSAT MSS data, and to study its effect on percentage of correct classification. The LOWTRAN-3 program, developed by the Air Force Geophysics Laboratories and based on a semi-empirical model, was used to calculate the atmospheric transmittance, in conjunction with Turner's model for correction of satellite data for atmospheric interference. It improved the contrast between different natural targets in the MSS LANDSAT data of Brasilia, Brazil. It also improved the classification accuracy of sugar canes by about 9%, in the MSS LANDSAT data of Ribeirão Preto, São Paulo, Brazil.

I. INTRODUCTION

Radiation from remotely sensed objects in the earth's environment is attenuated in its passage through the atmosphere. With the advent of LANDSAT, Skylab and other advanced earth monitoring satellites, it has become increasingly important to know to what extent the atmosphere affects the classification accuracy, using satellite multispectral scanner (MSS) data, of earth resources.

The Brazilian Institute of Space Research (INPE) operates a data receiving and a data processing station for the LANDSAT satellite and processes MSS data in the form of photographs, as well as computer compatible tapes. The objectives of the present project were: (1) To develop a suitable, computationally efficient, computer program to correct the tapes of LANDSAT's multispectral scanner (MSS) data for atmospheric interference; and (2), to study the effect of atmospheric interference on (A) the quality of LANDSAT MSS images for visual photo-interpretation and (B) the percentage of correct classification of the same data, using automatic pattern recognition techniques.

II. DETERMINATION OF ATMOSPHERIC TRANSMITTANCE

The calculation of atmospheric transmittance is normally difficult, because of the complicated nature of the radiative transfer equation and of the, usually incompletely known, constituency of the atmosphere at the time for which calculations are to be made. There have been innumerable investigations from which methods are derived for calculating atmospheric transmittance[1]. (1) Line-by-line calculations: the foundation for the line-by-line calculation is a set of parameters that describe the molecular lines in which radiation is absorbed and emitted. Many techniques[1], developed in these calculations, are designed to minimize the computational effort. Even with the time-saving approximations applied to the line-by-line calculation, the costs are often excessive for an accuracy beyond that required for correcting LANDSAT MSS data for atmospheric interference. (2) Band-Model Calculations: Although, in general, these techniques are more efficient computationally than line-by-line calculations, they still take considerably more computer time than, for example, the LOWTRAN 3 method described below. (3) The Aggregate method, developed by the Environmental Research Institute of Michigan (ERIM), is simply a compilation of the special forms of the band-models, assembled in a program. In this method, in certain wavelength regions, the conventional models are not used, but empirical fits to experimental data are used to determine the functional form of transmittance[1]. Since its spectral range

CH1430-8/79/0000-0053$00.75

(1 to 30 μm) does not include the visible wavelength region, it is not suitable for our purpose. (4) LOWTRAN 3 Method: The LOWTRAN 3 program[2] is based on a semi-empirical model and calculates the transmittance (averaged over a 20 cm^{-1} interval) for a given atmospheric path[3], at steps of 5 cm^{-1}, from 350 cm^{-1} to 40,000 cm^{-1} (0.25 to 28.5 μm).

The main assumptions made in this program are that the atmosphere can be represented by a 33-layer model, and that the average transmittance over a 20 cm^{-1} interval (due to molecular absorption) can be represented by a single parameter model, determined empirically using both laboratory transmittance data and available molecular line constants. The absorption coefficients for water vapor, ozone, and the combined effects of the uniformly mixed gases (CO_2, N_2O, CH_4, CO, N_2, and O_2) are digitized in this program.

A choice of six model atmospheres (1962 U.S. Standard Atmosphere, Tropical (15°N), Midlatitude Summer (45°N, July), Midlatitude Winter (45°, January), Subarctic Summer (60°N, July), and Subarctic Winter (60°N, January), is given, with an option for a seventh model, which can be inserted as a set of radiosonde data. The aerosol attenuation is calculated for a given visual range, using an interpolation | extrapolation scheme, with two aerosol models, based on measurements of continental aerosols under moderate visibility conditions (5 km and 23 km at sea level). The altitude, pressure, temperature, water vapor density, and ozone density for six model atmospheres, as well as the number of particles per cm^3 for two haze models (visual ranges of 5 and 23 km), are provided as basic input data.

This program was used for calculating the transmittance of the atmosphere because it is reasonably accurate, user-oriented, computationally very efficient, well documented and revised by the Air Force Geophysics Laboratories at regular periods of time, utilizing recent laboratory measurements and theoretical calculations.

III. CORRECTION OF LANDSAT MSS DATA FOR ATMOSPHERIC INTERFERENCE

Computer compatible tapes of LANDSAT MSS data were corrected using the 'atmospheric model for correction of spacecraft data', as given by Turner (1972)[4]. This model assumes a plane-parallel atmosphere but can be applied to the case of a realistic spherical atmosphere, if the nadir view angle is small, or if the satellite's altitude is not too great. The target was assumed to be diffuse. The eight parameters needed by the model are: wavelength, azimuth and zenith angles of the sun, azimuth and nadir view angles of the sensing device, height of the sensing device above the terrain, visual range at the ground, and average background terrain albedo.

The day, month, year, and local time of the satellite, along with the longitude and latitude of the ground scene, were used in a separate computer program to obtain the solar azimuth and zenith angles. The background terrain spectral albedo was estimated by the values of spectral reflectance of the known types of ground covers available in the literature. It was found that changing the scanning angle of the satellite from 0° to 10° had almost no effect on the calculated transmittance of the atmosphere. The elapsed time on a B-6700 computer to correct 4 images, each of 512 x 512 pixels (i.e. 1,048,576 pixels) for atmospheric interference, was about 15 minutes.

IV. EXPERIMENTAL RESULTS

LANDSAT MSS data of Brasilia, Brazil, were corrected using this algorithm and available radiosonde data. Figures 1 to 3 show the original image in band 4 (0.5 to 0.6 μm), band 7 (0.8 to 1.1 μm) and a color composite, respectively. Figures 4 to 6 show the respective figures 1 to 3 corrected for atmospheric interference.

Note that the corrected images have better contrast between natural targets, thus making it easier to discriminate between them by photo-interpretation. In addition, one can see textural features of certain areas like vegetation, roads, etc. better in the corrected images.

To arrive at an estimate of change in percentage of correct classification, after correction for atmospheric interference, LANDSAT MSS Data of Ribeirão Preto (July 1, 1977), was corrected for atmospheric interference using this algorithm. The Department of Remote Sensing of Earth Resources of INPE had classified the sugar canes in this area, using aerial photography. The original and corrected images gave classification accuracies of sugar canes to be 68.1% and 77.3% respectively, using the single-cell option of Image-100, as compared to the results obtained by aerial photography. Image-100 is a data processing system marketed by the General Electric Co. to extract thematic information and enhance multispectral imagery. Further experiments need to be done to establish if correcting LANDSAT MSS data for atmospheric interference significantly improves, statistically, the percentage of correct classification. Future plans include more experiments with the current algorithm, using a pixel-by-pixel maximum likelihood gaussian classifier, as well as a sample classifier, making the current algorithm computationally more efficient, and comparing the results to those of other algorithms of correcting satellite data for atmospheric interference reported in the literature, with respect to their effect on classification accuracy.

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Figure 1. Original Image in Band 4.

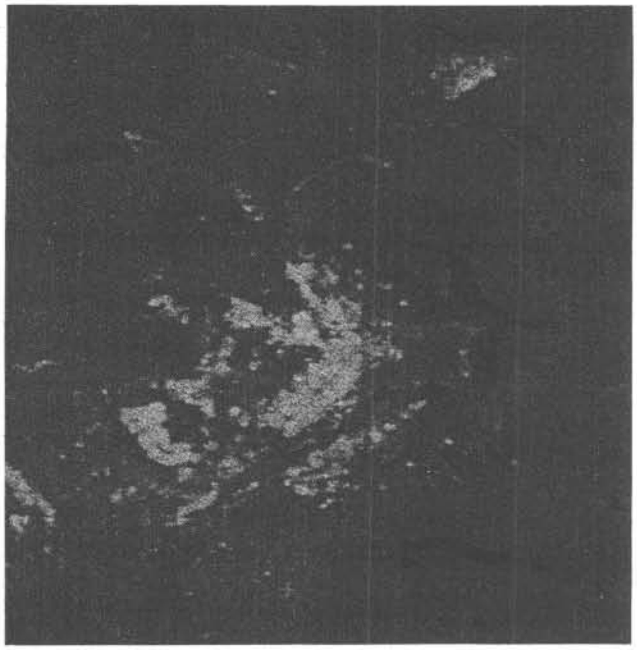

Figure 3. Original Image - Composite Color.

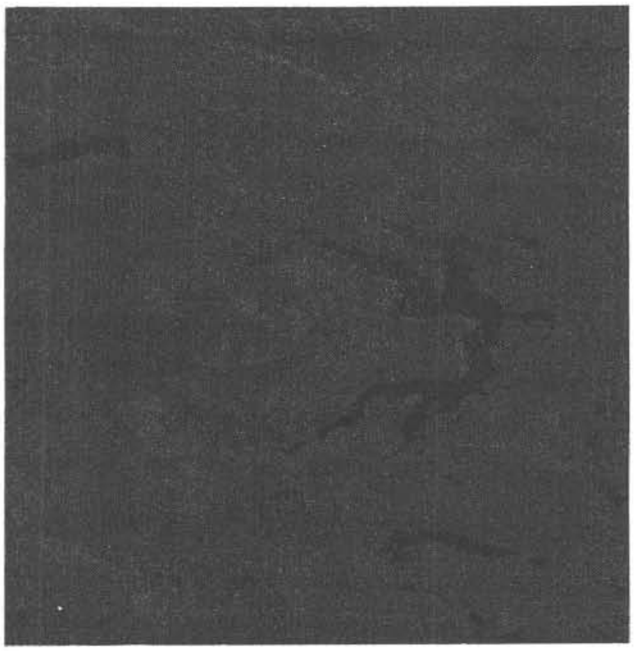

Figure 2. Original Image in Band 7.

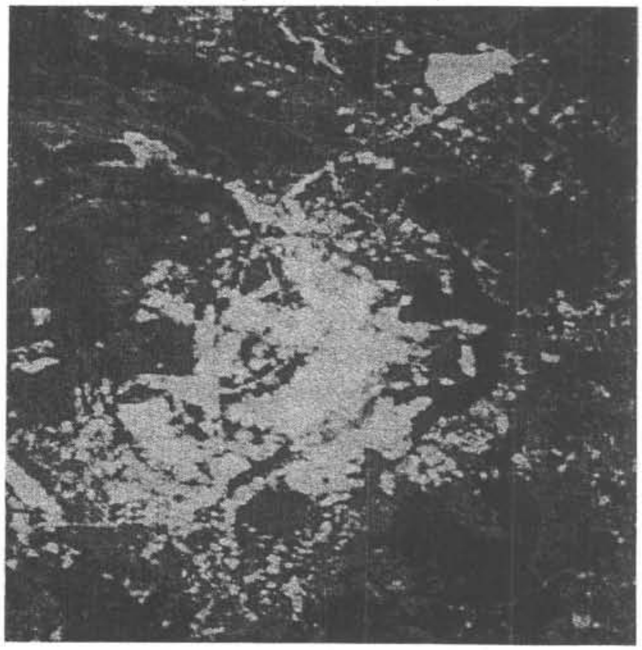

Figure 4. Corrected Image in Band 4.

Figure 5. Corrected Image in Band 7.

Figure 6. Corrected Image - Composite Color.