ACCOUNTING FOR ATMOSPHERIC EFFECTS IN AUTOMATED PROCESSING OF DATA ACQUIRED BY AN AIRBORNE MULTICHANNEL SCANNING SYSTEM

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The physical principles on which the normalization algorithm and the algorithm for automated processing of specific data acquired by an airborne multichannel scanning system are based are discussed.

Multiple scattering and absorption of sunlight in the atmosphere strongly affect the results of remote sensing of the underlying surface in the optical region of the spectrum. The nonorthotropic character of the reflection of the radiation by the underlying surface and multiple reflection of radiation in the system "atmosphere-underlying surface" also make an important contribution to the formation of the radiation field.[1,2] For this reason, to improve the accuracy of automated processing of remote sensing data a radiation correction, based on the solution of the boundary-value problem of radiation transfer in the atmosphere, must be made. In Refs. 1 and 3 improved classical analytical methods for solving the transfer equation are studied and examples of their application for solving remote sensing problems are presented. The computational possibilities of the ordinate method, the Monte-Carlo method, the method of successive„approximation, the method of spherical harmonics, and an improved method of spherical harmonics are compared in Ref. 3. Highly accurate methods for solving the transfer equations in order to make the radiation correction in high fluxes of aerocosmic video information in quasireal time cannot be used in practice, since significant amounts of computer time and large computer memories are required. In addition, it is necessary to know a large number of optical parameters characterizing the state of the atmosphere at the time the remote-sensing data are recorded. Such data are usually not available, since at the present stage the performance synchronous measurements of the optical parameters of the atmosphere is a quite difficult technical problem. For this reason approximate analytical solutions of the boundary-value problem of radiation transfer in the system "atmosphere-underlying surface" are of interest for implementing in practice the radiation correction to video data using approximation values of the optical parameters of the atmosphere obtained from the video data themselves.

An approximate analytical solution can be obtained by solving the transfer equation with an approximate analytical expression for the source function, obtained under different simplifying assumptions.[4–6] Within the framework of the two-flux approximation[5,6] the upward and downward fluxes are calculated at the first stage of the calculations and the intensities are calculated at the second stage.

In the approach employed in Ref. 5 for calculating atmospheric haze (there is no reflecting surface) at the first stage of the calculations the scattering phase function of the atmosphere is approximated by two delta functions, since the aerosol scattering phase function of the atmosphere is strongly peaked in the forward direction. For the intensity of the background haze (diffuse radiation, reflected at least once by the underlying surface) at the first stage of the calculations it is assumed that the intensity is independent of the direction of propagation within the upper and lower hemispheres. On the basis of the approach employed in Ref. 6 this independence assumption is made for the intensity of both the atmospheric haze and the background haze.

A modification of the approaches employed in Refs. 5 and 6 was used to make a quantitative estimate of the influence of atmospheric effects and the nonorthotropic nature of the reflection of the underlying surface on the intensity of the upward radiation; in this approach the process of interaction of the diffuse radiation with the atmosphere is described more accurately.[7,8] The conditions of a spring survey of winter wheat crops from an altitude of 10 km using an airborne multichannel scanning system (AMSS) with angular scanning in the range ± 25.6° from the nadir were modeled.[8] A numerical experiment was performed using the spectral reflective characteristics of winter wheat crops in four states; these characteristics were obtained with the help of the Nilson-Kuusk model, based on the concept of a turbid horizontally homogeneous medium.[9] It was shown that in order to achieve an admissible error in the classification of winter wheat crops by states under fixed conditions an atmospheric cohrection must be introduced on the basis of the approach employed in Ref. 8 under the condition that the optical thickness of the atmosphere τ_0 is known with an accuracy of the order of 0.005 at a wavelength of 0.55 μm.

The impossibility of evaluating accurately the optical parameters of the atmosphere at the time of the survey stimulated the development of approaches to correcting the AMSS video data based on the use of the statistical characteristics of the video data them selves. We noted that the standard automated processing based on the technological scheme first developed at the All-Unior Scientific-Research Center "AIUS-Agroresursy" for processing AMSS video data presupposes operation with a block containing 80–120 six-channel frames with 512 × 512 elements. This block consists of a series of frames corresponding to aerial surveys taken along straight flight paths.[10,11] The significant change in illumination (the survey time can be as long as four hours) and the dependence of the atmospheric effects and the reflection phase function of agricultural objects on the scanning angle, which result in a strong drift of the spectral signatures, made it necessary to improve significantly the method of statistical smoothing.[12] In particular, at the present time corrections for the change in illumination are made taking into account the movement of the aircraft. To take into account the angular distortions the intensity profile averaged within each series of frames is calculated - based of fragments of images with a uniform distribution of objects of different specific classes over the scanning angle.

A polynomial approximation of the dependence of the average angular profile of the intensity on the scanning angle and the survey time made it possible to realize a more efficient process for compensating for the variability of the intensity. Additional "smoothing" is performed bu reducing the data from different series to one average value of the intensity.[10,11]

The remaining uncompensated drift of the spectral signatures is taken into account with the help of a new type of classifier with polynomial approximation of the time dependence of the teaching data.[10,11] To improve the accuracy further the computational scheme takes into account directly the individual angular trends of each class; an original method was developed for evaluating the parameters of the angular dependence of the reference data using the overlap bands obtained by AMSS twice on neighboring flight paths.[13,14]

In conclusion we stress the need to correct for the quite significant effect of the background haze. This effect in principle cannot be eliminated on the basis of the statistical correction algorithm studied above, which makes it necessary to perform absolute calibration of the recording apparatus.

REFERENCES

1. K.Ya. Kondratyev, O.I. Smoktii, and V.V. Kozoderov, *Effects of the Atmosphere oh the Investigation of Natural Resourses from Space* (Mashinostroenie, Moscow, 1985).

2. G.M. Krekov, V.M. Orlov, V.V. Belov, et al., *Simulation in Problems of Remote Optical Sensing* (Nauka, Novosibirsk, 1986).

3. O.I. Smoktii, *Modeling of Radiation Fields in Problems of Space Spectrophotometry* (Nauka, Leningrad, 1986).

4. V.V. Sobolev, *Scattering of Light in Planetary Atmospheres* (Nauka, Moscow, 1972).

5. C.T. Wezernak, R.E. Turner, and D.C. Lyzenga, *"Spectralc reflectance and radiance characteristics of water pollutions"*. Report NASA-CR-2665 (1976), p. 218.

6. Y.J. Kaufman, J. Geophys. Res. **84**, No. C6, 3165 (1979).

7. V.P. Popov and A.A. Feoktistov in: *Interbranch Conference on the Application of the Results of Airborne and Exoatmospheric Studies of Earth for Agroprom USSR* (Nauka, Leningrad, 1987).

8. V.P. Popov and A.A. Feoktistov, *Problems of Designing an Automatic System for Monitoring of Agricultural Resources from Space*, All-Union Scientific Research Institute "AIUS-Agroresursy" Moscow (1987).

9. V.S. Artyomkov, I.I. Gorshkova, and K.Yu. Ross, "Comparison of some models of reflection of radiation by vegetation" in: *Interbranch Conference on the Application of the Results of Airborne and Exoatmospheric Studies of Earth for Agroprom USSR* (Nauka, Leningrad 1987).

10. G.S Popov, Yu.B. Skorobogatov, and A.A. Feoktistov, *To Investigate, Develop and Implement Mathematical and Cartographic Software for Computer-Processing Remote Sensing Data at the Main and Regional Centers of "AIUS-Agroresursy" System.* Interim Report, "AIUS-Agroresursy", Moscow (1986).

11. G.S. Popov, Yu.B. Skorobogatov, and A.A. Feoktistov, ibid (1987).

12. G.A. Alfyorov, V.S. Artyomkov, A.A. Feoktistov, et. al., *Remote Methods for Monitoring Agricultural Resources in the Problems of Memagement of Agricultural Production,* "AIUS-Agroresursy", Moscow, 72 (1985).

13. V.S. Artyomkov and A.A. Feoktistov, *"The problem of drift of spectral signatures in remote sensing of agricultural resources with an airborne multichannel scanning system"*. Express-Information No. 8–87, *Proceedings of the All-Union School-Seminar on the Application of Aerospace Information in Studies of Energy and Mass Transfer in Ecological Systems* (Nauka, Leningrad, 1987).

14. V.S. Artyomkov and A.A. Feoktistov, *Application of Aerospace and Space Technology for the Interests of the USSR State Committee of Agricultural Industries "AIUS-Agroresursy"*, Moscow, 38 (1986).