S E N S 2 0 0 8
Fourth Scientific Conference with International Participation
SPACE, ECOLOGY, NANOTECHNOLOGY, SAFETY
4–7 June 2008, Varna, Bulgaria

PREPROCESSING OF SPECTROMETRIC DATA

Valentin Atanassov, Georgi Jelev, Lubomira Kraleva

Space Research Institute - Bulgarian Academy of Sciences
e-mail: vatanassov@space.bas.bg

Keywords: *imaging spectrometer data preprocessing, methods.*

Abstract: *Preprocessing is an important part of analysis of imaging spectrometry data and is relevant to data quantitative estimation. The basic appropriate methods for elimination of sensor-related effects of spectrometric data, such as dark current correction and spectral and radiometric resampling, are described and highlighted. Some corresponding approaches illustrating the procedures for data preprocessing are presented and the obtained results are shown.*

1. Introduction

Notwithstanding their young age, spectrometric measurements have about 30-year-long history, while Remote Sensing of the Earth from space occupies is of essential importance for the development of modern science and technology. The application area of remotely sensed spectral data is expanding continuously to incorporate new applications, such as ecologic monitoring of endangered areas, monitoring the global changes of natural resources and environment, climate changes etc. The conclusion can be drawn that spectral images make it possible to map biophysical and biochemical changes of the Earth's surface and the state of atmosphere with unprecedented accuracy. The observed tendencies show that we need better observation and understanding of the basic lines for sustainable development of our resources and the preservation of the environment.

During the last decade, the development of modern technologies resulted in vigorous development of remote sensing systems and apparata (space, airplane or ground-based) *[1,2]*. However, the expected enhancement of classification accuracy tends to lag behind *[3]*. The major reasons for this lie in the great complexity of remote sensing measurements and the insufficiently intensive investigation of the sources of indefiniteness in remotely sensed data *[4,5]*. This calls for development and improvement of the modelling methods, the data processing techniques, and the identification and classification methods for the objects from the observed scene, to improve information quantity and quality, without expensive changes in equipment hardware.

Actually, to score new achievements we should improve the quality of used data by consistent and comprehensive efforts in the field of preliminary processing and improvement of remote sensing systems.

2. Methods

Spectrometric measurements, as a new area in remote sensing, require new approaches towards data acquisition, data preprocessing and deriving information from synthesized spectral images. These approaches constitute an important part of the analysis of spectrometric data and are mandatory for quantitative analysis of these data. In the Remote Sensing area the radiation that has fallen onto the sensor is registered after it has passed from the source to the examined object and back to the sensor *[6]*. The objective of the measurement is to identify the examined object by its characteristics, such as form, size, composition, temperature, and other parameters of interest to the researchers. The information about the object is contained in the instrument's response. The purpose of the studies is to provide for determination of the functional relation between the radiation reflected by the examined object and the output signal of the device by appropriate preprocessing of the obtained data.

To achieve this purpose, system analysis must be performed from data acquisition to information deriving. This analysis will make it possible to reveal and identify the sources of indefiniteness in the measurements and will demonstrate the need of applying data preprocessing before using data classification algorithms. In the quantitative aspect, this high indefiniteness is substantiated not only by the type of the used instrument, but also by the sources forming the overall power of the reflected emission registered by the instrument. In a number of practical cases, the unambiguous determination of the characteristics of the examined objects and consequently, their identification, turns to be impossible without accompanying synchronous or "quasi-synchronous" ground-based measurements, providing additional spectral data for the examined scene.

Spectrometric measurements require as well solving a number of multidimensional problems, since the measured value of the emission at the sensor's input is a function not only of the radiation reflected by the examined object, but of other factors, too, such as polarization and location of the emission arriving at the input aperture, its direction and spectral distribution. The sources of spectrometric measurements errors feature a broad spectrum; therefore, in the cases where such measurement data will be used for subsequent analyses, these errors should be necessarily accounted for, and each of them should be localized, analyzed and characterized. The proper identification of the sources of indefiniteness, occurring during the measurement process, provides not only to determine their quantity, but also to apply preprocessing of such data for the purpose of excluding or at least minimizing their influence on the output results, to enhance these data's comparability and improve the integrity of the derived information *[9,10].*

The major objective of the preprocessing of spectrometric data is to provide possibility for the most accurate possible determination of the functional relation between the radiation reflected by the investigated object and the output signal of the device through proper preprocessing of the obtained data.

The identified objective may be achieved by investigating and applying the basic stock of methods and resolving the following major tasks:

- conducting system analysis in remote sensing to localize, characterize and minimize the impact of the sources of indefiniteness through preprocessing of the data during the period between their acquisition and deriving of information, which includes the following subtasks:

- investigating the impact of radiation propagation from the examined object and back to the sensor to characterize the parameters' impact on data quality;

For the purpose of the studies, the main measurement equation of a spectrometric system may be used *[11]*:

$$(1)\qquad S = R_\lambda\,[\,\tau_{u,\lambda}\,(\rho_{g,\lambda} + \rho_{g,adj,\lambda}\,w_a)\pi^{-1}\cos\varphi\,(\tau_{d,\lambda} + \tau'_{d,dif,\lambda}/\cos\varphi)\,E_{0,\lambda} + L_{atm,}\,]\,\Delta\lambda\,\Delta A$$

From equation *(1)* we express functional *(2)*:

$$(2)\qquad S = f[\tau_{d,\lambda},\ \tau'_{d,dif,\lambda},\ \varphi,\ \theta,\ \rho_{g,\lambda}\ ,\ \tau_{d,adj,\lambda},\ \tau'_{d,dif,adj,\lambda,}\ \rho_{g,adj,\lambda,}\ w_a,\ \tau_{u,\lambda,}\ \tau'_{u,dif,\lambda,}\ L_{atm}],$$

where: S – output sensor signal, $\tau_{d,\lambda,}$ $\tau'_{d,dif,\lambda}$ $\tau_{d,adj,\lambda}$, $\tau'_{d,dif,adj,\lambda}$ – admission coefficients of directly fallen and diffuse radiation, φ – falling angle, θ – observation angle, $\rho_{g,\lambda,}$ $\rho_{g,adj,\lambda}$ – reflection coefficients, w_a - weighing coefficients accounting for the closeness effect, $\tau_{u,\lambda,}$ $\tau_{u,dif,\lambda}$ – admission coefficients from the studied surface to the sensor, L_{atm} – atmospheric backscattered radiation, R_λ – spectral instrument sensitivity characteristics, ΔA – studied surface in the sensor's input aperture.

The derived functional accounts for the influence of the various complex input signal elements on the sensor's output signal *[12]* and provides to make detailed analysis of the noise sources and indefiniteness in remote sensing measurements, including localization, analysis, and characterization of each of them.

- investigating the methods for image restoration in the special and spectral areas;

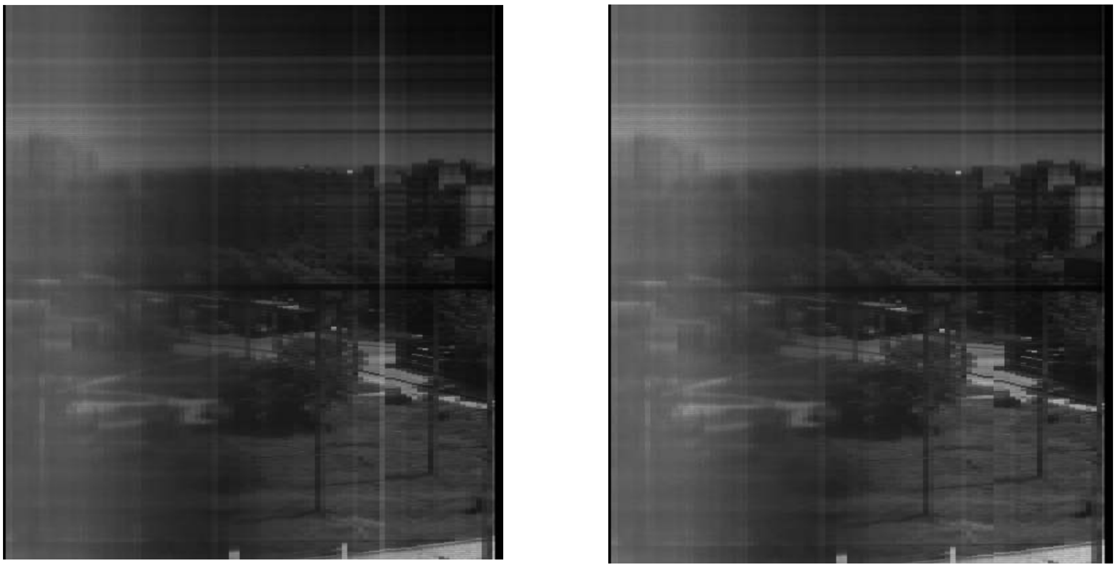
A number of spectral image restoration methods exist, the most popular of them being:

Nearest Neighbor Resampling:

The interpolated pixel value is:

$$(3)\qquad L_i(x_p,y_p) = L(x_p + \Delta x,\ y_p + \Delta y),$$

where: L is the original radiance value, and $(\Delta x^2 + \Delta y^2)^{1/2}$ is the minimal distances to the selected position.



a b

Fig. 1. Spectral image collected in spectral band 550nm, a – original image, b – corrected image.

Linear Interpolation Resampling:

(4) $L_i(x_p,y_p) = (L_i(x)_{xp} + L_i(y)_{yp})/2,$

where $L_i(x)_{xp} = (L(x\text{-}1)_{xp} + L(x+1)_{xp})/2$ and $L_i(y)_{yp} = (L(y\text{-}1)_{yp} + L(y+1)_{yp})/2$, $L(x)_{xp}$ and $L(y)_{yp}$ yp are the linearly interpolated continuous functions of radiance in across track and along track directions.

Bilinear Interpolation Resampling:

(5) $L_i(x_p,y_p) = L_i(x, y)_{triang} \big|_{xp,yp}$,

where: $L_i(x, y)_{triang} \big|_{xp,yp}$ represents a bilinear interpolation.

The selection of an appropriate spectral image restoration method depends on a number of factors: sensor spectral and spatial resolution, synthesized image class, studied cover type, data acquisition conditions etc. The differences of the various interpolation methods used in the data calibration process need to be analyzed further in future work.

3. Conclusions

1. The conduct of a preprocessing, including a detailed and comprehensive analysis of the noise and non-uniformities introduced in the process of data acquisition will provide to minimization, and to a certain extent, prevent the examined objects' classification errors under various measurement conditions. This will also demonstrate the need of preprocessing data before using them in classification algorithms.

2. The conduct of an appropriate preprocessing of remotely sensed spectral data provides to: reduce the effects of non-uniformity in the spectral images by formulation of requirements for the individual blocks of the spectral system and the location platform; verify remotely sensed spectral data acquired by space-based instruments, intercalibrate and compare spectral data and simulate the characteristics and parameters of future hyperspectral sensors.

3. Based on the performed system research in the preprocessing area, the modern tendencies for design and development of remote sensing systems will be confirmed, expanded, and to a certain extent, assisted.

References:

1. K r a m e r H. J. Observation of the Earth and Its Environment. Springer, Berlin. 1996.
2. A t a n a s s o v V., A. K r u m o v, V. V a s i l e v, N. V a s i l e v. Prototype of a Vis-NIR Imaging Spectrometer. 1998 ASPRS-RTI Annual Conference, Tampa, Florida, March 30 - April 4, 1998 Conference Proceedings, pp.1402-1407.
3. S t a e n z K. A Decade of Spectrometry in Canada. - Canadian Journal of Remote Sensing, vol. 18, № 4, 1992. p. 187.
4. A t a n a s s o v V. I., B. B. P e e v, N. N. V a s s i l e v, V. K. V a s s i l e v. Hyperspectral Imaging Spectrometer as a Power Tool for Ecological Monitoring. Journal of Balkan Ecology, vol.4, № 2, 2001. pp. 168 – 170.
5. A t a n a s s o v V., G. J e l e v, L. K r a l e v a. Imaging Spectrometer Data Correction. Scientific Conference "Space, Ecology, Safety – SES'2005" with International Participation, 10-13 June 2005, Varna, Bulgaria. Conference Proceedings, book 1, pp.221 – 226.
6. A t a n a s s o v V., L. K r a l e v a, G. J e l e v. Noise and Uncertainties in Remote Sensing Spectroscopy Measurements. III Scientific Conference "SENS'2007" with International Participation, 27-28 June 2007, Varna, Bulgaria. Conference Proceedings. pp. 170-174. (in Bulg.).
7. A t a n a s s o v V., G. J e l e v, L. K r a l e v a. Measurement Equation in Spectrometric Systems. III Scientific Conference "SENS'2007" with International Participation, 27-28 June 2007, Varna, Bulgaria. Conference Proceedings. pp. 174-179. (in Bulg.).
8. A t a n a s s o v V., G. J e l e v. Algorithm for Dark Current Characterization of Imaging Spectrometer. Aerospace Research in Bulgaria, vol. 19, 2004. pp. 77-83.
9. S c h l ä p f e r D., J. N i e k e and K. I t t e n. Spatial PSF non-uniformity effects in airborne pushbroom imaging spectrometry data. IEEE Transactions on Geoscience and Remote Sensing, Vol. 45(2):458-468. 2007.
10. S c h l ä p f e r D., M. S c h a e p m a n, and P. S t r o b l. Impact of Spatial Resampling Methods on the Radiometric Accuracy of Airborne Imaging Spectrometer Data. 5th Int. Airb. Rem. Sens. Conference and Exhibition, VERIDIAN, San Francisco, pp. 8.