THE I.R.O.E. ACTIVITY FOR THE AVIRIS CAMPAIGN IN EUROPE

Alessandro Barducci
Regione Toscana - Environment Dept.
Florence, ITALY

Ivan Pippi
C.N.R. - I.R.O.E.
Florence, ITALY

Abstract. This paper presents the activity of the I.R.O.E. in preparation to the next AVIRIS campaign in Europe. On the basis of the experience acquired during various remote sensing campaigns utilizing different aerospace sensors, we have developed a dedicate software to perform remote sensing image display and processing. This software program, named XIMATEL and written in C and FORTRAN-77 languages, uses the X-Window System graphics environment and allows the user to perform multitasking operations as well as to share graphics resources of different workstations connected through the Ethernet network link. XIMATEL provides the following relevant operations: multispectral and multitemporal analysis, geometrical and atmospheric corrections, spatial filtering, Fourier analysis, and thematic classification. In addition some preliminary results are presented and discussed.

I. INTRODUCTION

The remote sensing of the environment performed by aerospace sensors operating at visible and infrared wavelengths is an important tool for studying the Earth surface. Unfortunately the satellite sensors now available have poor spectral resolution for many applications.

For this reason a new generation of high spectral and spatial resolution sensors are planned to be placed in the near future on board the polar orbiting platforms. In order to test the performance of such instrumentation, some airborne imaging spectrometers have been built up [1]. Among them the AVIRIS (Airborne Visible/Infrared Imaging Spectrometer) represents the prototype for the spaceborne HIRIS (High-Resolution Imaging Spectrometer).

The AVIRIS operates in the whisk-broom imaging mode and has a spectral coverage from 0.40 to 2.44 um divided into 210 useful channels. The instantaneous field of view is 1 mrad and the number of cross-track pixels is 614. Since summer 1987 the AVIRIS, built by the JPL, has been operated on board the NASA ER-2 aircraft at an altitude of about 20 Km over many different sites in the United States. During next June and July the AVIRIS will fly for the first time in Europe.

II. I.R.O.E. ACTIVITY

The I.R.O.E. is interested in the development of new remote sensing sensors and has already been involved in various remote sensing campaigns utilizing different active and passive aerospace sensors. Moreover in the past it has received some AVIRIS images from the JPL in order to evaluate the sensor performance. Particular attention has been paid to the development of new software packages which can perform the image processing and visualization starting from a great amount of data.

In order to evaluate the quality of the AVIRIS data collected over Italy during the next campaign in Europe, we will utilize the program named XIMATEL, developed in our institute.

A. SOFTWARE DEVELOPMENT

To satisfy the portability and compatibility requested by different potential users, this procedure has been developed in standard programming environments. The main program, which manages any graphics task, has been developed using the C programming language and the X-Window System graphics environment, and is connected to a wide data base containing spectral signatures of different constituents of the Earth surface, and to a library of subroutines, written in FORTRAN-77 language, for the image processing.

The X-Window System provides a user-server model in which the server carries out display and input services as demanded by the user application code. Communications between server and application are realized by means of a subroutine set, called X-lib, that provides building and decoding of message packets. The physical separation of the windowing system and of the server from the user application, based on a communication link, lends itself to implementations using high speed local area networks as the medium for message exchange. By allowing this separation user application can be executed on nodes different from the own workstation, eventually taking advantage of special or more powerful hardware.

As shown in Fig.1, XIMATEL as well as X-lib are device independent and adding or changing peripherals they only require X-server extension. This feature provides high portability for XIMATEL, getting the X-Window System more diffused.

The Fig.2 shows the manager panel of XIMATEL as displayed by a VAXstation 3500 running under the VMS operating system. It is made up of a menu bar, a window for input and output operations, and two windows for histogram and spectral features display. The six pull down menus enable various commands for image visualization and processing (such as load and save images trough disk files, false colours display, image corrections, image classifications, etc.). The main operations are discussed in the following sections.

1. IMAGE CORRECTIONS

Aerospace remote sensing images are affected by geometrical distortions as well as radiometric troubling. The geometrical distortions, due to perspective effects and optical aberrations, change the pixel positions and therefore mainly affect such applications as cartography. This effect is proportional to the field of view of the imaging system and is hence important for airborne observations but negligible in spaceborne ones. On the other hand optical degradation of the images, that happens during the radiation transfer within the atmosphere and sensor optics, changes the pixel radiance and its spectral features and therefore gives rise to errors when thematic classification or multispectral or multitemporal analysis are carried out. It is therefore necessary to eliminate these effects on the remotely sensed images before the image processing goes on.

(a) GEOMETRIC DISTORTION. A FORTRAN-77 subroutine of XIMATEL performs the geometric correction. This subroutine re-samples the image, positioning the new pixels at a priori computed locations so as to preserve the original metrics of the scene. The new pixel value of the corrected image by interpolation is calculated, allowing the user to choose betwèen three different functions: the nearest pixel value, the straight line and the cubic splines. However this procedure does not correct for such factors as aircraft roll, pitch and true heading, ground holography and optical aberrations of imaging system, which generally create unpredictable distortions.

(b) ATMOSPHERIC EFFECTS. The aim of image remote sensing generally should be to evaluate the scene reflectance for visible and near infrared observations, or the scene emitted radiance for thermal infrared ones. It is nevertheless well known that the measured radiance is affected by the atmosphere as stated by the following relationship:

$$L_o(\lambda,\theta) = \frac{1}{\pi}[E(\lambda,\theta)\rho(\lambda) + \epsilon(\lambda)B(\lambda,T)]\exp[-\tau(\lambda)\sec(\theta)] + L_u(\lambda,\theta) \qquad (1)$$

where θ is the zenithal distances of the line of sight, Lo the observed radiance, E the irradiance at the ground, ρ the reflectance, ε the emissivity, B the Planck function and τ the atmosphere optical thickness. Lu is the up-welling radiance due to atmospheric scattering and thermal emission [2]. In the previous equation the cross-talk between different pixels, for example produced by atmospheric aerosol and telescope optics, is neglected.

If a physical model of atmosphere and solar irradiance is known, then it is possible to invert Eq.(1). XIMATEL uses the LOWTRAN 7 computer code [3] to calculate E, τ and Lu, and then retrieves the reflectance ρ for visible images or the blackbody radiance $\varepsilon\cdot B$ for thermal infrared ones.

2. IMAGE PREPROCESSING

XIMATEL implements a set of FORTRAN-77 subroutines that carries out a series of mathematical elaboration on the images. These applications are regarded by XIMATEL as preprocessing and comprise the following relevant tasks: image enhancement by histogram equalization or hyperbolization, and smoothing.

To reduce the image noise by smoothing techniques, two different methods have been used: the selective local average, as edge preserving, iterative enhancement and local pixel selective smoothing, and special processing to eliminate fine amplitude components as symmetric hysteresis smoothing and median filter.

Furthermore XIMATEL allows us to perform the Fourier analysis of the images. A FORTRAN-77 subroutine of the XIMATEL achieves the two dimensional fast Fourier transform (FFT) of the image, and its power spectrum is displayed on the screen. It is also possible to multiply the FFT by an user supplied weighting function (filter), or by the FFT of another image (correlation) and then to compute the inverse transformation. The Fourier analysis also is a powerful tool to evaluate the imaging system performances, because it allows to recognize and to suppress such imaging noise as spikes or periodic patterns.

3. IMAGE PROCESSING

The processing is regarded by XIMATEL as the final step of image working out. To achieve the thematic classification, those applications that involve the recognition and the identification of structures and features in the images held are here executed. For this purpose XIMATEL utilizes various FORTRAN-77 subroutines, all based on two different approaches: histogram and spectral analysis.

The histogram approach is based on the maximum likelihood, or Bayes optimal classification. It treats the histogram as a multi-modal probability distribution given by a weighted sum of various probability density (Gaussian) functions, each one corresponding to different classes. The main problem, which is to compute the probability density functions and the respective weights, is solved by least squares fit, so that the maximum number of recognizable classes is only limited by the amount of grey levels of the raw image. XIMATEL performs maximum likelihood classification on single image and then display the image map together with synthetic and true histogram.

XIMATEL realizes the spectral analysis by looking for maximum correlation between the spectrum of each pixel of the image and the available laboratory reflectance spectra of different compounds stored into a data base. The output consists of the spectral response display of both image and laboratory spectra.

Furthermore XIMATEL provides a set of binary operators which may be applied to image couples. The operators set comprises the four arithmetical operations and the following bitwise operators: and, or, exclusive or.

B. PRELIMINARY RESULTS

To evaluate the AVIRIS performances, we have applied the XIMATEL procedure to data acquired over Cuprite and Moffett Field in 1989. Applying the histogram and the Fourier transform, the images at the central wavelength of each spectrometer have been analysed. The relevant result is the recognition of some periodic noise patterns present in all the considered images, as reported in Fig.3 for the channels 16 and 192. Their power spectra exhibit two spikes and some other vertical straight lines with a widespread frequency range, probably due to electromagnetic interferences or mechanical vibrations.

In addition the image classification using the maximum likelihood method and the spectral features analysis have been performed. We remark that the high spectral resolution and the extended photometric dynamics, typical of the AVIRIS data, allow to obtain detailed thematic maps.

III. CONCLUSIONS

The next European AVIRIS campaign will provide the remote sensing of the environment in several test areas. The extremely high data amount requires the use of powerful hardware and software processing systems. The I.R.O.E. is mainly interested in AVIRIS performances evaluation, also in comparison with the other sensors flying at the same time like the TIMS and the TMS.

Therefore we have realized the XIMATEL computer code, running under the X-Window System, which performs multitasking operation as well as shares graphics resources of different workstations. It is also equipped with a subroutine set that enables us to perform the full image working out: from correcting for atmospheric effects and geometrical distortions up to the thematic classification. This software has been tested utilizing the AVIRIS data acquired over Cuprite and Moffett Field in 1989 and received by the JPL.

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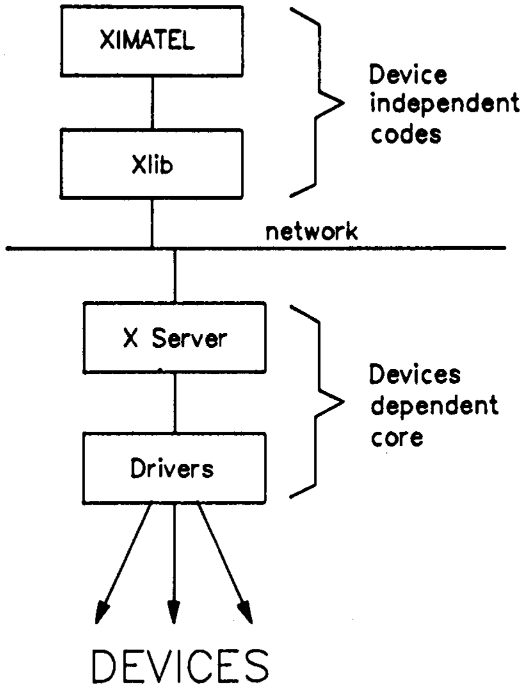


Fig. 1. The workstation configuration under X-Window System.

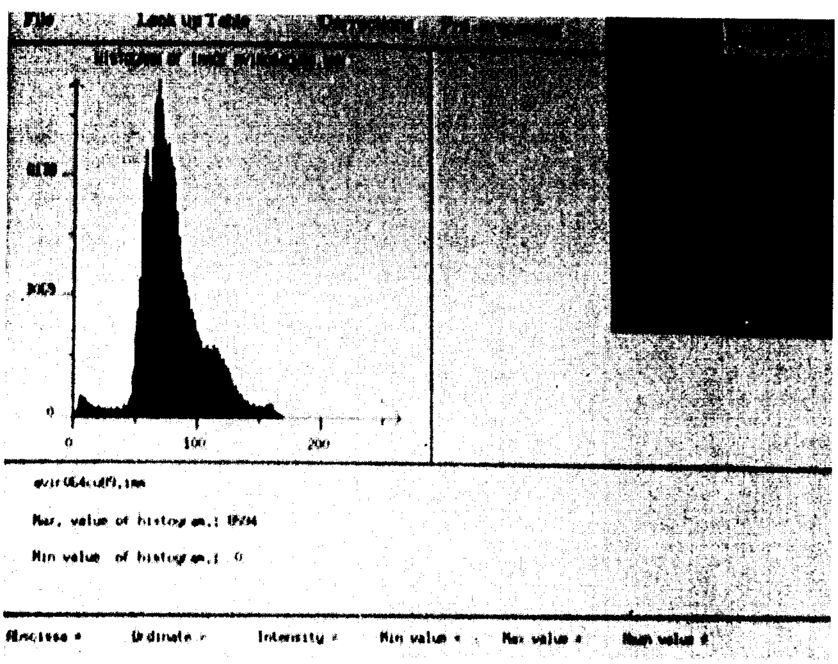


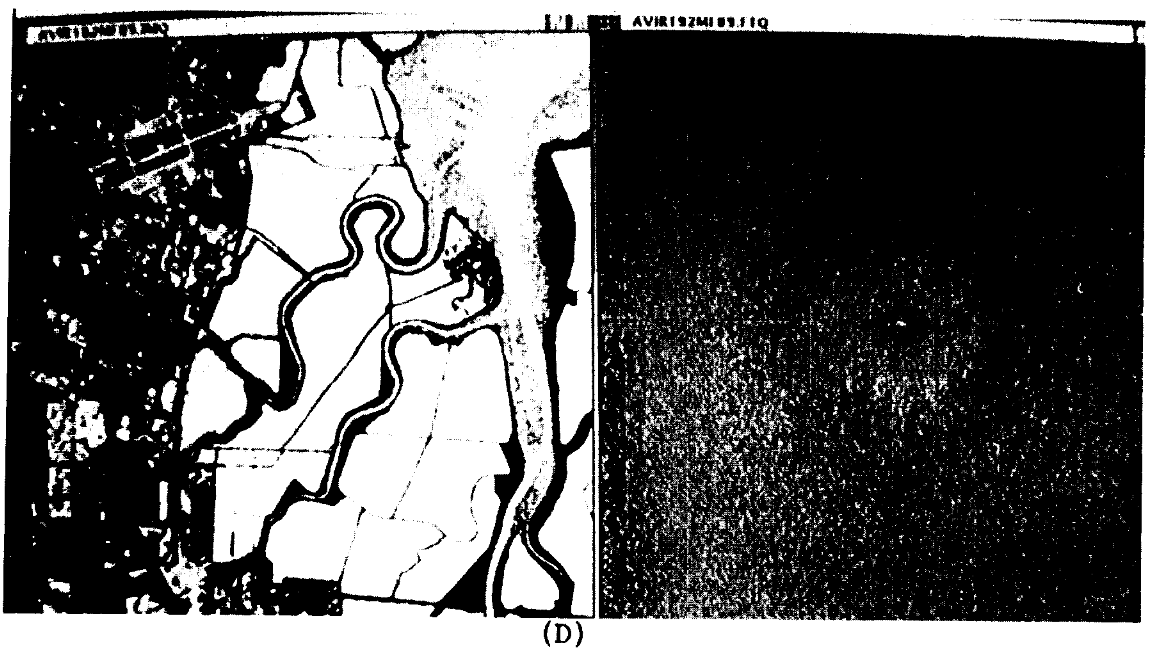
Fig. 2. XIMATEL panel manager.

(A)

(B)

Fig. 3. AVIRIS spectral images and their power spectrum (FFT). (A) Cuprite channel n.16 (0.5425 um); (B) Cuprite channel n.192 (2.1333 um);

(C)



(D)

(cont'd)

Fig. 3. AVIRIS spectral images and their power spectrum (FFT). (C) Moffett Field channel n.16 (0.5425 um); (D) Moffett Field channel n.192 (2.1333 um).