ANALYSIS OF HIGH SPECTRAL RESOLUTION DATA ON A PERSONAL COMPUTER

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ABSTRACT

This paper describes the specifications of a personal computer-based software package suitable for the analysis of high spectral resolution data sets such as Airborne Imaging Spectrometer (AIS) and Airborne Visible/InfraRed Imaging Spectrometer (AVIRIS). The software has been designed to allow imaging spectrometer (or any other spectral) data to be analysed in numerical, graphical and image form. Particular features of note include: flexible data entry, support for integer and real data types, wavelength indexing of spectra and spectral curve extraction.

INTRODUCTION

There are a growing number of remotely sensed data sets which have the ability to highlight both the spectral and spatial properties of a target area. Unfortunately there has been very little concurrent software development to aid the analysis of such data sets. One notable exception is the SPectral Analysis Manager developed by the Jet Propulsion Laboratory (Mazer et. al. 1988). However, this software was developed specifically for AIS data and problems were encountered when processing AVIRIS data. In addition, adding to SPAM's spectral library can be difficult and until recently the software only operated under the VAX/VMS environment. This led the authors to develop a system for analysis of high spectral resolution data, termed T-Spectra. The software is designed to process image data with an almost infinite number of spectral channels from either laboratory or airborne/spaceborne sensors and is built around a data reading engine intimately tied to wavelength information.

The advent of spectrometer data demands a new approach in image processing; changing functionality away from display and enhancement towards techniques for spectral processing. A number of researchers have identified priority areas for software improvement for dealing with data generated by the EOS programme (Warton and Newcomer 1989, Halem 1989).

Current research using imaging spectrometer data shows

that there is a need for rapid evaluation, calibration, and pre-processing before substantive interpretation is possible. Therefore, software needs to be orientated towards spectral and numerical functions. Equally important, data should be easily entered, displayed, and saved in a form that preserves the history of the procedures applied to it. At the core of spectral analysis are qualitative and quantitative methods for comparing spectra. Therefore, it is important to retain a quantitative description of essential data such as wavelength position, spectral sampling, and statistical properties of the data to avoid confusion and aid later analysis.

The software described in this paper specifically addresses the computational and graphical requirements of high spectral resolution data. It has been implemented to run on a standard IBM Personal Computer and has been successfully applied to analyse AVIRIS data from NASA's 1989 Airborne campaign, providing a simple and effective tool for integrating laboratory and image-based spectral data.

SOFTWARE DESIGN

The software has been developed with the following principal objectives:
1. Software must read image or laboratory data from a wide range of data types.
2. There should be no limit to the spectral dimension of the data cube.
3. The data should be structured and processed according to the wavelength start and stop position of each data channel.
4. The code should be structured and where possible conform to ANSI standards to ensure portability and maintenance.

Thus far, a system is available for IBM PCs with VGA (or EGA) graphics. It contains certain fundamental image processing functions such as spatial filters and image enhancement routines as well as the following spectral analysis capabilities(see figure 1):

1. The data entry and conversion functions can handle any combination of Bands, Samples, and Lines and convert among these.
2. Spectral plots are directly tied to image coordinates and can be compared visually with library spectra.
3. Scatter plots are mapped to image coordinates; thus the location of each point on the plot may be found in the image. This is of particular value for identifying likely spectral end-members.
4. The software has a menu-led interface.

Figure 1. The structure of the T-SPECTRA software showing its major functions.

User Interface
(Forms)

File structure
(Data types, header structure)

Arithmetic	**Statistics**	**Filters**	**Graphics**	**Spectra**
-Single band	-Whole image	-Stat	-Hist	-Pixel
-Multi band	-Sub area	-Spatial	-Scatter	-Lib
-Strips				

Display
-Window
-Zoom
-Sub-sample

User interface

The interface has two screens; a text screen with sliding bar menus is used for displaying information such as commands, responses, help, statistics, and file management tasks (see figure 2); a graphics screen is used to display images, graphs and spectral plots (see figure 3).
A series of pull-down menus on the graphics screen allow the user to set area and statistical parameters for spectral curve extraction and plotting. One feature of the interface is its ability to remember the parameter settings used to generate spectra. Therefore, it is possible to reload a saved spectrum and the file structure will retain its spatial and statistical properties.

Screen forms are provided to assist with the description of the format of data to be entered into the system. The user is presented with an appropriate template from which to choose or specify image or spectral file details. Details on the form not known to the user or the system are calculated automatically without need to exit the form. In the future the interface will supply the necessary menus for users to spawn their own functions, supplied as executable programs.

In addition, the MS-DOS system may be accessed directly or simply called to generate directory listings.

File structure

The file structures are a novel feature of the T-SPECTRA software. Our approach has been to define three separate but interrelated header structures for images, spectra, and graphical plots. For example, the image header structure contains essential information about the data type, format, and wavelength position for each data channel. The corresponding structure for a spectrum contains details of its genesis(eg. image position and statistical processing), wavelength range

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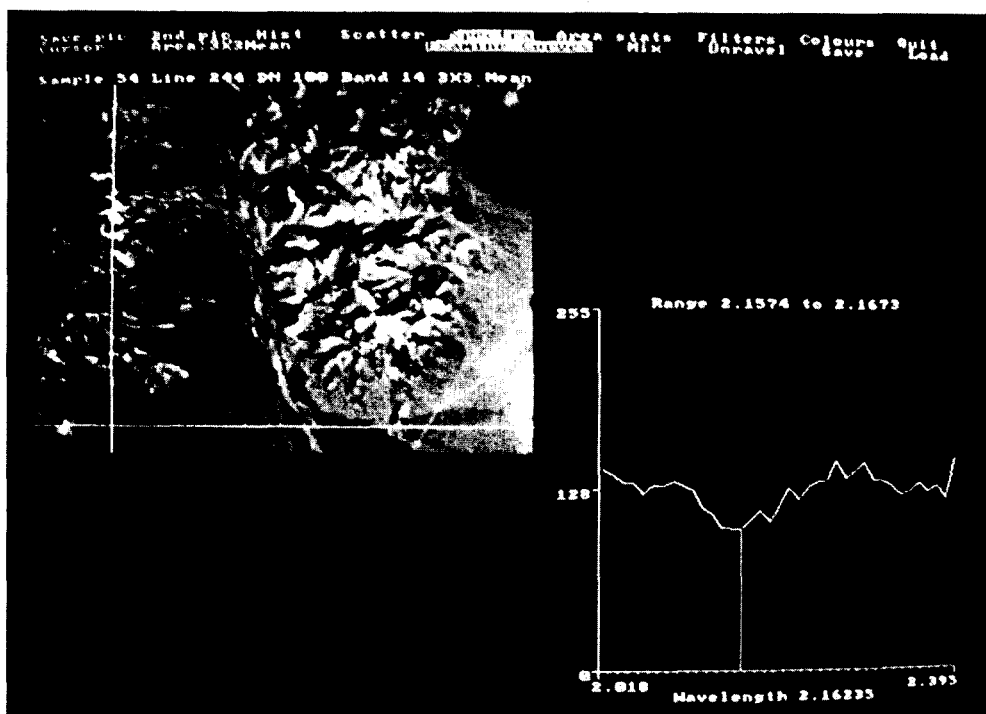Figure 2. (See Slide 22) The T-SPECTRA menu interface showing interactive selection of input image format.

Figure 3. (See Slide 23) The graphics interface showing an albedo image from AVIRIS SWIR data processed with the log residual technique. Spectra from a 3*3 area have been interactively extracted and these correspond closely with the minerals kaolinite and alunite.

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and bit fields for recording information about the shape of the spectral curve.

The image structure supports a wide range of data types, and, where necessary, will process data in 8-byte double precision arithmetic (table 1). These types are supported by a memory manager which loads the function for the appropriate data type and so it is possible to provide optimal support for any data type.

Table 1. Data types supported

Data types supported	bytes
unsigned char	1
signed int	2
float	4
double	8

The user defines the system's file structure with reference to a 'look up' file which tells the system how the data is formatted and where to find it. This file can be viewed and edited in ASCII format with any text editor. This approach gives enormous flexibility and negates much of the need for file conversions.

All arithmetic calculations are processed in double precision since many data sets produce absolute numerical reduction to physical values. Separate data files can be processed in an operation regardless of data type or file format (BSL, SBL etc.).

The file handling procedures are designed to be freely read in order to facilitate data exchange and integration.

SPECTRAL ANALYSIS

There are two methods of analysis for spectral data. First, spectra may be generated interactively from multi-channel imagery from a screen which displays both a spectral plot and a single channel reference image simultaneously. An exact position is selected by moving a mouse or cursor keys and the program then plots the raw data from disk as a spectral plot. Figure 3 shows an example of spectra being generated from SWIR AVIRIS 1989 data from Cuprite mining district, Nevada. Results from the analysis of these data are presented in Hook and Rast (1990) in this volume. In figure 3 the spectra represent the mean of a 3 by 3 kernel with no threshold defined. Up to sixteen spectra may be loaded (any number may be viewed) and interrogated using the **examine curves** option. This allows a moving cursor to range along the wavelength axis and display the FWHM positions for each AVIRIS channel for interpretation. Loaded spectra may be saved to a spectral library or simply as an ASCII file for export.

Spectra may also be displayed as a full screen plot or extracted from a graphical plot (see next section). In full screen mode, as with the image mode, both saved image and

laboratory spectra may be plotted and processed. In this mode functions are available for calculating hull quotients, spectral feature wavelength positions, and additive linear mixtures.

GRAPHICAL CAPABILITY

The system can produce spectral (or wavelength) plots, histograms and scatter plots. These may be saved or printed and are designed to relate directly to image data through the tying together of their coordinate systems.

Spectral plots

Any number of spectral channels may be plotted; however, the plot may be resampled spectrally depending upon the screen mode chosen. It is possible to re-scale both the intensity and the wavelength axes in order to view data at full spectral resolution or to compare spectra with differing spectral bandpasses. Multiple spectra may be plotted for any given wavelength range and each spectrum is resampled to that range. Each spectrum has a descriptive structure which contains its wavelength file and 16 bit fields are used to store information about its shape. Currently we are evaluating new methods for describing spectral shape for feature recognition purposes.   Features include:
- plot tied to image coordinate system
- graphical display of multiple spectra
- linear mixing of n number of spectra
- save spectrum and re-display on same axis
- define spatial kernel for spectral data extraction
- print spectrum or spectra

Spectral extraction from scatterplots

It is possible to extract spectra directly from scatter plots.
This function takes advantage of the file system to locate image coordinates from plot coordinates. Where image locations are superimposed in plot space the coordinates are displayed and the user can either plot the spectrum or skip to the next location. Spectra can also be saved for later analysis.
Since image coordinates are stored during scatter plot generation it is possible to mark or mask the image location(s) of any plotted point.
Features include:
- Locate any plot coordinate on image
- Locate any image coordinate and locate on plot
- Set density slice (colours) for either band on plot
- View data in scaled or unscaled form
- Save and output to printer

BASIC IMAGE PROCESSING

There are a number of general purpose image processing functions incorporated into the software. These allow arithmetic and statistical manipulation of the data. For example, the system will allow the following arithmetic functions to be performed on images and on parts of images, defined as strips of rows or columns.

- log10, loge, sine, cos, tan, arcsine, arccos, arctan, sqrt
- linear equations, [+,-,*,/,constant]
- multiple ratio, average

Strips (user defined rows or columns in the data)
- [+,-,*,/], sum, average, min, max

Statistics may be calculated on any number of selected bands or any area within the data cube (samples, lines, bands). Basic statistics are held in the header structure for image scaling for display purposes or can be calculated when required.
- min, max, mean, median, mode, variance, stdev

Filters

Filters are an important component of spectral analysis software, both for noise reduction and image enhancement purposes.
All image filtering is carried out in the spatial domain using convolutions defined by kernels. These are divided into mathematical and statistical transformations.
1. Mathematical
The following operations may be defined by a kernel of n^2 where n > 1 and is an odd number.
- Laplacian, Sobel, Inverse laplacian,Directional (edges)
- definable, Roberts (only applied as 2 by 2 kernel)
2. Statistical: -mean, median, mode, min, max, range, stdev
Several of the functions have been implemented as rapid screen enhancement routines in the spectral analysis mode.

CONCLUDING REMARKS

T-SPECTRA does not duplicate existing image processing software, instead it provides a data processing and development tool for high spectral resolution data. The software allows the user considerable flexibility for integrating and processing spectral data.

It differs from most image analysis systems developed for broad band multi-spectral data such as LANDSAT TM in that it processes data according to wavelength position. It is therefore possible to integrate both imaging spectrometer and laboratory spectroradiometer data easily with wavelength referenced plots.

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The data reading engine has been written to allow flexibility of data format and data type as well as lifting restrictions on the number of spectral channels which may be processed.

Finally the program will run on **any** IBM (or strictly compatible) Personal Computer. It requires a VGA graphics card for the display, a minimum of 256k of RAM, a MS-Mouse, and a reasonably sized fixed disk drive to store the data. The software functions with or without a math co-processor and MS-mouse, and will run on any IBM PC platform operating under MS-DOS 3.3 or above.

For additional information please contact any of the authors at the addresses listed at the beginning of this paper.

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