EXELIS

Visual Information Solutions

ENVI Classic Tutorial: Basic Hyperspectral Analysis

Basic Hyperspectral Analysis

This tutorial shows you how to extract spectra from regions of interest (ROIs), how to create directed color composites, and how to use 2D scatter plots for simple classification. You will use 1995 Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) atmospherically corrected apparent reflectance data for Cuprite, Nevada, USA. The subsetted data cover the 1.99 to 2.48 µm range in 50 spectral bands, approximately 10 nm wide. You will extract ROIs for specific minerals, compare them to library spectra, and design RGB color composites to best display the spectral information. You will also use 2D scatter plots to locate unique pixels, query the data distribution, and perform simple classification.

You should be familiar with the concepts presented in the tutorial "Introduction to Hyperspectral Data" on page 2 before beginning this tutorial.

Files Used in this Tutorial

Download data files from the Exelis website.

File	Description
`cup95_at.int (.hdr)`	AVIRIS atmospherically corrected reflectance data
`jpl1.sli (.hdr)`	JPL Spectral Library in ENVI® spectral library format with header
`usgs_min.sli (.hdr)`	USGS Spectral Library in ENVI Classic format with header
`cup95_av.roi`	Saved ROI locations

References

Clark, R. N., G. A. Swayze, A. Gallagher, T. V. V. King, and W. M. Calvin, 1993, The U. S. Geological Survey Digital Spectral Library: Version 1: 0.2 to 3.0 mm: U. S. Geological Survey, Open File Report 93-592, 1340 p.

Clark, R. N., A. J. Gallagher, and G. A. Swayze, 1990, Material absorption band depth mapping of the imaging spectrometer data using a complete band shape least-squares fit with library reference spectra: in Proceedings of the Second Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) Workshop, JPL Publication 90-54, p. 176 - 186.

Clark, R.N., T. V. V. King, M. Klejwa, G. Swayze, and N. Vergo, 1990, High Spectral Resolution Reflectance Spectroscopy of Minerals: J. Geophys Res. 95, 12653-12680.

Grove, C. I., S. J. Hook, and E. D. Paylor, 1992, Laboratory reflectance spectra of 160 minerals, 0.4 to 2.5 Micrometers: JPL Publication 92-2.

Kruse, F. A., A. B. Lefkoff, and J. B. Dietz, 1993, Expert System-Based Mineral Mapping in northern Death Valley, California/Nevada using the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS): Remote Sensing of Environment, Special issue on AVIRIS, May-June 1993, v. 44, p. 309 - 336.

Kruse, F. A., and A. B. Lefkoff, 1993, Knowledge-based geologic mapping with imaging spectrometers: Remote Sensing Reviews, Special Issue on NASA Innovative Research Program (IRP) results, v. 8, p. 3 - 28.

Define ROIs

You can use ROIs to extract statistics and average spectra from groups of pixels. You can define as many ROIs as you wish in any displayed image.

Load AVIRIS Data

1. From the ENVI Classic main menu bar, select **File > Open Image File**. A file selection dialog appears.
2. Select `cup95_at.int`. Click **Open**.
3. In the Available Bands List, select **Band 193** and click **Load Band**.

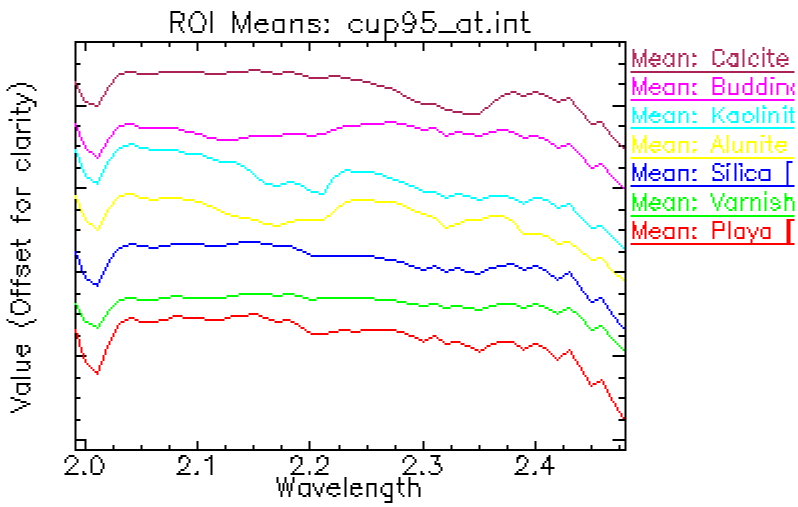
Create and Restore ROIs

1. From the Display group menu bar, select **Overlay > Region of Interest**. An ROI Tool dialog appears.
2. Draw a polygon ROI anywhere in the image by clicking repeatedly to define straight-line segments. Or, draw a free-form polygon by clicking and dragging inside the image.
3. Right-click to complete the ROI and to close the polygon. Right-click again to lock the ROI in place.
4. In the ROI Tool dialog, click **Stats**. An ROI Statistics Results dialog appears with an embedded plot window that shows the following:
   - Mean spectrum (white)
   - First standard deviation above and below the mean spectrum (green)
   - Minimum and maximum envelope containing all of the spectra in the ROI (red)
5. From the ROI Statistics Results dialog menu bar, select **File > Cancel**.
6. In the ROI Tool, click **Delete** to delete the selected ROI.
7. From the ROI Tool dialog menu bar, select **File > Restore ROIs**. An Enter ROI Filenames dialog appears.
8. Select `cup95_av.roi`. Click **Open**. This file contains previously defined ROIs for known areas of specific minerals. The ROIs are listed in an ENVI Classic message dialog and loaded into the ROI Tool dialog as shown in the following figure:

9. In the ROI Tool dialog, select the **Off** radio button to enable pixel positioning in the display group.
10. From the Display group menu bar, select **Tools** > **Profiles** > **Z Profile (Spectrum)**.
11. Move the crosshairs in the Zoom window to a pixel inside of an ROI.

Extract Mean Spectra from ROIs

1. In the ROI Tool dialog, click **Select All**, followed by **Stats** to extract statistics and spectral plots of the selected ROIs.
2. In the ROI Statistics Results dialog, click **Select Plot** and select **Min/Max/Mean**.
3. Examine the spectral variability of each ROI by comparing the mean spectrum (white) with the first standard deviation spectra (green above and below the mean) and the envelope spectra (red above and below the mean).
4. Click **Playa (Red) 28 points** at the top of the ROI Statistics Results dialog, select other ROIs, and view their minimum, maximum, and mean data values.
5. In the ROI Statistics Results dialog, click **Select Plot** and select **Mean for all ROIs** to plot the average spectrum for each ROI.
6. Right-click in the plot window (in the ROI Statistics Results dialog) and select **Stack Plots**. This option offsets spectra for comparison.
7. Right-click again in the same plot window and select **Plot Key**. The plot should look similar to the following:



8. Compare the spectral features of each spectrum and note unique characteristics that might allow mineral identification.
9. You can compare spectral library signatures to the ROI mean signatures for calcite, buddingtonite, kaolinite, and alunite. Right-click inside the plot window (in the ROI Statistics Results dialog) and select **File > Input Data > Spectral Library**.
10. In the Spectral Library Input File dialog, click **Open** and select **Spectral Library**.
11. Select `jpl1.sli`. Click **Open**. Click **OK** in the Spectral Library Input File dialog.
12. In the Input Spectral Library dialog, select one of the following:
    - CALCITE C-3D
    - BUDDINGTONITE FELDS TS-11A
    - KAOLINITE WELL ORDERED PS-1A
    - ALUNITE SO-4
13. In the **Y Data Multiplier** field of the Input Spectral Library dialog, enter **1000**. Click **OK**. The spectral library signature appears in the plot window.
14. Try comparing spectra from the USGS spectral library (`usgs_min.sli`) with image spectra and the JPL spectral library.
15. When you have finished, close the ROI Statistics Results dialog. Keep the ROI Tool dialog open for the next exercise.

Discriminate Mineralogy

Design color images to discriminate mineralogy:

1. In the Available Bands List, select the **RGB Color** radio button. Select **Band 183**, **Band 193**, and **Band 207**. Click **Load RGB**.
2. From the Display group menu bar, select **Tools > Profiles > Z Profile (Spectrum)**. A Spectral Profile plot window appears. Red, green, and blue lines mark the positions of the bands used to make the RGB color-composite image.
3. In the ROI Tool dialog, select the **Off** radio button and browse spectra near your ROI locations.
4. Notice where the selected RGB bands fall with respect to spectral features in the previously displayed mean spectra and how the spectral features affect the color observed in the image.
5. Click and drag the colored bars in the Spectral Profile to change them to the desired bands. One way to enhance specific materials is by centering one color bar in an absorption feature and the other two on opposite shoulders of the feature.
6. Right-click inside the Spectral Profile and select **Load New RGB Combination** to load the new bands into the display group.

   After inspecting a few sites, you should begin to understand how the color-composite colors correspond with the spectral signature. For instance, the alunitic regions appear magenta in the RGB composite because the green band is within the alunite absorption feature, giving a low green value, while the red and blue bands have nearly equal reflectance. The combination of red and blue results in a magenta color for pixels containing alunite.

   Based on the above results, try these exercises:

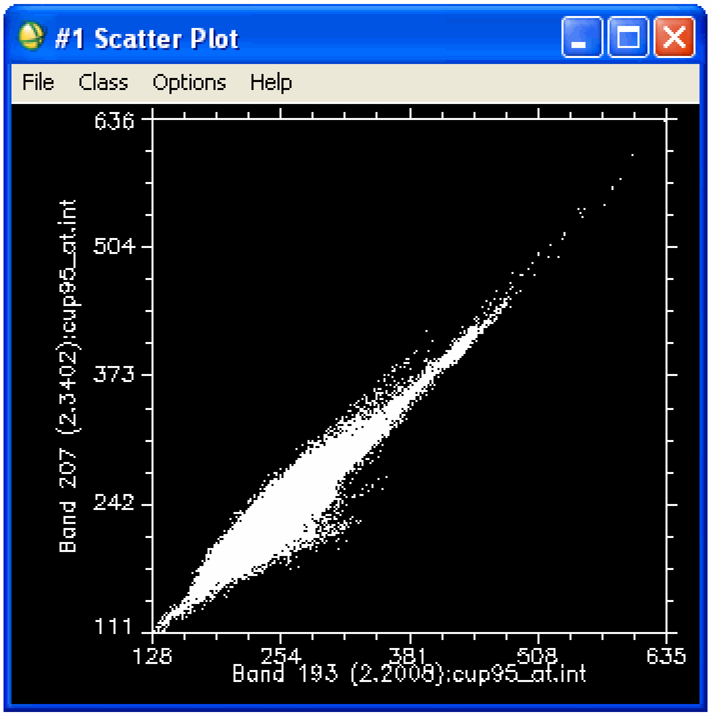
7. Predict how certain spectra will look, given a particular pixel's color in the RGB image.
8. Explain the colors of the training sites, in terms of their spectral features.
9. Design and test specific RGB band selections that maximize your ability to map certain minerals, like kaolinite and calcite.

Close Plot Windows and ROI Controls

1. Close all open plot windows by selecting **Window > Close All Plot Windows** from the ENVI Classic main menu bar.
2. From the ROI Tool dialog menu bar, select **File > Cancel**.

2D Scatter Plots

1. From the Display group menu bar, select **Tools > 2D Scatter Plots**. A Scatter Plot Band Choice dialog appears.
2. Under **Choose Band X**, select **Band 193**. Under **Choose Band Y**, select **Band 207**. Click **OK**. A Scatter Plot window appears with a plot of the x and y apparent reflectance values:



Density Slice the Scatter Plot

1. From the Scatter Plot menu bar, select **Options > Density Slice** to automatically density-slice the scatter plot. The colors show the frequency of occurrence of specific apparent reflectance combinations for the two plotted bands. Purple is the lowest frequency, progressing through the colors blue, green, yellow, to red as the highest frequency of occurrence.
2. From the Scatter Plot menu bar, deselect **Options > Density Slice** to turn off the color slice.

Dancing Pixels

1. Click and drag inside the display group to show "dancing pixels" in the Scatter Plot. The red pixels in the Scatter Plot correspond to those pixels within a 10 x 10 patch around the cursor in the display group.
2. Try to predict the locations of certain image colors in the scatter plot, then check them. Notice the shape of the red dancing pixels.

3. Click and drag the middle mouse button in the Scatter Plot to show dancing pixels in the display group. The red pixels in the image correspond to those pixels within a 10 x 10 patch around the cursor in the Scatter Plot. Note the spatial distribution and coherency of the selected pixels.
4. Change the patch size in the Scatter Plot by selecting **Options > Set Patch Size** from the Scatter Plot menu bar, and observe the difference.

Scatter Plots Linked to a Spectral Profile

1. From the Scatter Plot menu bar, select **Options > Z Profile**. A file selection dialog appears.
2. Select `cup95_at.int` and click **OK**. A blank Scatter Plot Profile window appears.
3. Right-click in the Scatter Plot to extract the spectrum for the corresponding pixel.
4. Compare spectra from the different parts of the Scatter Plot and note the spectra that appear at the "points" of the plot versus the center of the plot.

Scatter Plot ROIs

The Scatter Plot can also be used as a quick classifier.

1. Draw an ROI inside the Scatter Plot by clicking and dragging to define a polygon.
2. Right-click to close the polygon. Image pixels with the two-band characteristics outlined by the polygon are colored red in the display group.
3. You can start a new class by performing one of the following steps:

   From the Scatter Plot menu bar, select **Class** and choose a different color.

   OR,

   From the Scatter Plot menu bar, select **Class > New Class**.
4. Draw another polygon ROI in the Scatter Plot. The corresponding pixels are highlighted in the selected color in the display group.
5. You can clear (remove) a class by performing one of the following steps:

   From the Scatter Plot menu bar, select **Options > Clear Class**.

   OR,

   Click the middle mouse button outside (below) the plot axes.

   OR,

   From the Scatter Plot menu bar, select **Class > Items 1:20 > White**. Draw a white polygon around the highlighted region you want to clear and right-click to close the polygon. White acts as an "eraser."
6. Use Scatter Plot to work backwards to see where certain pixels occur in the image.

7. You can convert classes to ROIs that act as training sets for classification using all of the bands by selecting **Options > Export Class** or **Export All** from the Scatter Plot menu bar. ROIs exported in this fashion appear in the ROI Tool dialog and are available for subsequent supervised classification. You can convert them to a classification image by selecting **Classification > Create Class Image** from the ENVI Classic main menu bar.
8. From the Scatter Plot menu bar, select **Options > Clear All** to remove the ROIs from the Scatter Plot and display group.

Image ROIs

The Scatter Plot also functions as a simple classifier from the image.

1. From the Scatter Plot menu bar, select **Options > Image ROI**.
2. Draw some polygon ROIs in the display group. The ROIs are mapped to and highlighted in the Scatter Plot with the selected color. All of the matching pixels in the image are inversely mapped to the display group and highlighted in the same color, as though you had drawn the scatter plot region yourself. This is the simplest form of two-band classification.
3. Note the correspondence between image color and scatter plot characteristics.

Scatter Plots and Spectral Mixing

Can you explain the overall diagonal shape of the data cloud in terms of spectral mixing? Where do the purest pixels in the image fall in the scatter plot? Are there any secondary "projections" or "points" on the scatter plot?

1. Choose some other band combinations to scatter plot by selecting **Options > Change Bands** from the Scatter Plot menu bar. Try one pair of adjacent bands and other pairs that are spectrally distinct.
2. How do the scatter plots change shape with different band combinations? Can you describe the n-D "shape" of the data cloud?
3. When you are finished, select **File > Exit** from the ENVI Classic main menu bar.

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