

Lab 4 Spectral Mixture Analysis

1. Objectives

- (1) Understanding the concept of subpixel fractions of land cover types.
- (2) Recognized the important of endmember selection in spectral mixture analysis.
- (3) Conduct spectral mixture analysis with the Model Module in Imagine.

2. Theory

The theory of spectral mixture analysis is quite simple. Assuming the reflectance value of a pixel is the area weighted average reflectance of the land cover types that cover the pixel. i.e.

$$S = f_1R_1 + f_2R_2 + \dots + f_{n-1}R_{n-1} + (1 - f_1 - f_2 - \dots - f_{n-1})R_n$$

Where f_i is the fraction of the land cover type i and $f_1 + f_2 + \dots + f_n = 1$. It is obvious from the equations above, we need at least (n-1) equations above in order to solve for the (n-1) unknowns of f_i . It appears that we need (n-1) spectral bands to solve for the (n-1) subpixel fractions. In fact, it is not the number of spectral bands that determine the number of unknowns that can be solved, but the number of data dimensionality. As we know that the remotely sensed data from spectral bands are often highly correlated, we cannot use all the bands simultaneous to construct an equation as shown above. Mathematically, it is the number of data dimensions that determined that number of endmembers that can be included in the spectral mixture analysis.

Though the theory is quite simple, it quite difficult to implement due to the difficulty in identifying the spectral signatures of endmembers. In this lab, we intends to extract the subpixel portions of vegetation, impervious surface and dark features (shadows, water etc.). Therefore, we have three endmembers, we need two orthogonal bands to solve for the three subpixel fractions. We will do this with band 3 and 4, Tasseled Cap brightness and greenness index and Principal component 1 and 2 in this study and compare the results.

3. Steps

1) Start Imagine, click Interpreter/Spectral Enhancement.../Principal Comp..., the principle component analysis dialog window will appear. Select chapelhill-etm24may2002.img from R:\data\images\ directory as Input File. For the Output File, save it as chapelhill-etm24may2002-pc1-3.img in your student folder. Make sure the Data Type for Output is Float Single. Check the box Write to file for both Eigen Matrix and Eigenvalues. A file name is automatically given for each, but the default locations for saving them may not be your student folder. Make sure these files are saved in your folder. Set the Number of components Desired to 3. Click OK, and the principal component analysis will be done in a few seconds. Open a viewer and

display the principal component image, take a careful look the PC image, and note differences between the PC image and the original RGB=321/432/453.

2) Click Interpreter/Spectral Enhancement.../Tasseled Cap.... The Tasseled Cap (Kauth-Thomas transformation) dialog window will appear. Select the Input File as chapelhill-etm24may2002-ref.img which is the file that you corrected for atmosphere effects in Lab 2. Set the Sensor to be Landsat 7 Multispectral, the Output File as chapelhill-etm24may2002-ref-TC.img to be saved in your student folder. Tasseled Cap transformation does not provide an option for how many transformed component one wishes to keep. The output file contains all six components. Open the Tasseled Cap transformation image and display the image as RGB=123. Compare it with the principal component image as well as the original images in RGB=123/432/453. Note the differences.

3) Click Classifier in the main menu bar and select Feature Space Image..., the Create Feature Space Images dialog will appear. Set Input Raster Layer as chapelhill-etm24may2002.img. You will see an Output Root Name is automatically specified. But the location may not be right. You need to save the output file in your student folder. You will also see they are many output file names listed under Feature Space Layers as there are six bands in the image. We will only need chapelhill-etm24may2002_3_4.fsp.img, click the number in the first column corresponding to the image. This will select the feature space image, and the selection will tell the software that this is the only feature space image I want. All other feature space image will not be produced. click OK.

4) Open the feature space image you just generated in a viewer. You will see a feature space image for band 3 and 4. Move your cursor over the image, and find the following values:

Vegetation: B3=V3 (e.g. 39), B4=V4(e.g. 180)

Dark Features: B3=D3, B4=D4

Impervious (bright features): B3=I3, B4=I4

Do the same thing for the principal component image using PC1 and PC2 and Tasseled Cap transformation image using Brightness and Greenness. Find the endmember signatures similarly for the above three endmembers and record them.

5) Find a scratch paper, you will need to solve for f_1 (vegetation fractions), f_2 (Impervious fractions) from the following equations:

$$\begin{cases} f_1V3 + f_2I3 + f_3D3 = DN_3 \\ f_1V4 + f_2I4 + f_3D4 = DN_4 \\ f_1 + f_2 + f_3 = 1.0 \end{cases}$$

Where f_1 , f_2 and f_3 are unknowns, and V_3 , I_3 , D_3 , V_4 , I_4 , and D_4 are the endmember signatures in band 3 and band 4. DN_3 and DN_4 are the DN values in the image, which are known for any given image. Do the same thing for the PC and TC images.

6) Open Model Maker from the main menu. Draw a flow diagram similar to the one you draw in lab 2. Double click the input raster icon and specify the chapelhill-etm24may2002.img as input image. Double click the circle in the middle, and specify the expression for calculating f_1 , note please replace the endmember signatures with the actual value you identified, and the DN_3 and DN_4 by the layer 3 and layer 4. Double click the output raster icon, specify the output file names as vegetation_fraction_etm34.img. Please specify the output file type as “float single”. Do the same thing for f_2 , the impervious endmember, and specify the output as impervious_fraction_etm34.img.

7) Repeat step 6) for vegetation and impervious surface using principal component 1 and 2 and specify the output files as vegetation_fraction_pc12.img and impervious_fraction_pc12.img.

8) Repeat step 6) for vegetation and impervious surface using Tasseled Cap transformation component 1 and 2 and specify the output files as vegetation_fraction_tc12.img and impervious_fraction_tc12.img.

9) Do a layer stack for vegetation_fraction_etm34.img, vegetation_fraction_pc12.img and vegetation_fraction_tc12.img to produce a three band image vegetation_fraction_etm34pc12tc12.img. Display each of the 3 band vegetation fraction image in a viewer in RGB=123. In this image, the gray areas are area where all three approach estimate similar subpixel vegetation fractions. In areas that appear red, the first approach generated significantly higher estimation than the other two approaches. Similarly, you can see how the estimate vary in other colors. Then set RGB to one layers at a time (e.g. RGB=111), and swipe the Ikons panchromatic image and visually analyze how well each approach works.

10) Repeat 9) with the impervious fractions.

4. Lab Report

- 1) Report and eigen values and eigen vectors for the principal component analysis. Calculate how much information PC1 and PC2 carry.
- 2) Compare the first and second eigen vectors with the transformation coefficients of Tasseled Cap transform for brightness and greenness. See how they related.
- 3) Include the three feature space images from which you identified the endmember signatures in your lab report along with the actual value of endmember signature.
- 4) Include the Stacked three band vegetation fraction image in your lab report, describe how well the three approaches agree.
- 5) Include the Stacked three band impervious fraction image in your lab report, describe how well the three approaches agree.

- 6) Discussions: Based on your understanding from the work done above, discuss what are the potential sources of error in spectral mixture analysis?