Aim of Lesson

To learn how to classify vegetation species using Compact Airborne Spectrographic Imager (CASI) imagery.

Objectives

1. To calculate a vegetation mask based on a Normalized Vegetation Difference Index NDVI.
2. To learn how to define a region of interest based on the field survey data and imagery.
3. To learn how to classify an image using Spectral Angle Mapper SAM.
4. To learn how to assess the accuracy of the classification.

Background Information

This lesson relates to the Sections 9.1.4.1, 9.1.5 and 12 of the HyperTeach Theory Syllabus. For further details about the techniques involved readers are recommended to read these sections. This lessons describes a method to classify vegetation species in the nature reserve 'De Westhoek' using CASI imagery. 'De Westhoek is located at the West coast of Belgium near the French border.

Different government institutions require actual, frequently updated vegetation maps of the active dunes, mud flats and salt marshes along the Belgian coast. The Flemish governmental institution 'Administratie Waterwegen en Zeewezen' (AWZ), uses this information for coastal protection to prevent the coast from flooding caused by storms. The 'Instituut voor Natuurbehoud' (IN), has a need for vegetation maps to monitor biodiversity and ecological recovery. In addition, these maps are suitable for scientific research on the variety and evolution of vegetation in the different nature reserves.

Software

An ENVI® student license is required to carry out the lesson.

Image data

The CASI sensor was mounted in a Dornier 228. A Global Positioning System (GPS) and an Inertial Navigation System (INS) was installed in the aircraft to measure respectively the position (lat, long, height) and attitude (pitch, yaw, roll) of the aircraft. A GPS base station was used to obtain more accurate differential GPS measurements of the aircraft's position. The CASI data was recorded at a spatial resolution of 1 m x 1 m. The reflected solar radiance was measured in 48 spectral bands within the wavelength range from 415 nm to 956 nm. Hyperspectral data was collected along the complete Belgian coast (approx. 66 km) in October 2002.

The raw data (i.e. the digital numbers generated by the CASI sensor) was radiometrically, geometrically and atmospherically corrected to obtain geocoded reflectance images. The collected data is registered in 12 bits (0:4096) and stored in band sequential (bsq) format, which means that the different bands are stored sequentially.

To distinguish between the different data files collected along the Belgian coast, the filenames are coded. In this exercise we will use part of the flight line flown above 'De Westhoek'. The file is named L1102rag10_Wh_cp and is coded as follows: L11 indicates the flight line; 02 indicates that the data was collected in 2002; rag stands for radiometric, atmospheric and geo-corrected data; 10 indicates a ground or pixel resolution of 1 m x 1 m; _Wh indicates that the data is a cutout (Wh stands for Westhoek) of a larger data file. Cp indicates that some noisy bands are cut and noise is removed from the remaining bands. How noise removal was performed can be found in Hands-on Lesson 2: Data preparation.

Field survey data

GPS locations of three different reference vegetation types (grass, shrub and dune vegetation) were measured during a field survey. The reference plots have at least a diameter of 5 m of homogeneous vegetation cover. Table 10.1 lists the geographical location (Belgian Lambert 72) of the central points of the measured vegetation plots.

#	Type	Eastern (m)	Northern (m)
1	Shrub	23151.0	199293.0
2	Shrub	23076.0	199201.0
3	Shrub	22686.0	199205.0
4	Grass	22494.0	199136.0
5	Grass	23097.0	199270.0
6	DuneVeg	23066.0	199478.0
7	DuneVeg	22789.0	199411.0
8	Shrub	23020.0	199189.0
9	Grass	23142.0	199229.0
10	Shrub	22950.0	199186.0
11	Grass	22507.0	199188.0

>> Table 10.1: Belgian Lambert 72 coordinates (m) of different vegetation plots.

Lesson outline

Creating a vegetation mask

Whenever a large number of spectral bands have to be investigated (which is mostly the case with hyperspectral imagery!) displaying individual bands one by one is very time consuming. The Z profile or spectral profile of an individual pixel gives a clear overview of the different spectral band values of the corresponding pixel. This spectral profile or reflectance spectrum is characteristic for each material on the Earth's surface and is the basic for hyperspectral image classification.

Action: In the 'ENVI' main menu use the 'Open Image File' option to open and display file L1102rag10_Wh_cp.

Hint: In the ENVI main menu [ENVI] use: <File> <Open Image File>

Action: Use the 'Available Bands List' to load band 1 in the blue (B) channel, band 14 in the green (G) channel and band 24 in the red I channel.

Hint: You have learned in "Lesson 2: Data preparation" why these channels are used. Trace back if you don't remember.

Action: Explore some pixel spectra. Compare the spectral profile of water pixels with the spectral profile of sand pixels and the spectral profile of vegetation pixels. Notice the difference in spectral profile in relation to the different materials at the Earth's surface.

Hint: In the 'Image' window use: <Tools> <Profiles> <Z Profile (Spectrum)…>
Move the 'Zoom' window around to investigate different pixels.

Question 10.1: How can you distinguish vegetation spectra from non-vegetation spectra? In other words, how does a typical vegetation spectrum looks like?

Hyperspectral images contain a large amount of data. All redundant information needs to be removed in order to decrease computation time. In this lesson the aim is to identify or classify different vegetation types, therefore all non-vegetation pixels can be regarded as redundant information and can be masked out. The vegetation mask is created using the 'Normalized Difference Vegetation Index' (NDVI).

NDVI = (near IR band – red band) / (near IR band + red band)

Action: Calculate an NDVI image using bands 17 and 28, with wavelengths 676 nm and 803 nm respectively. In this case band 17 is located in the red area of the electromagnetic spectrum at 676 nm, band 28 is located at the NIR plateau at 803 nm. Both wavelengths are ideally suited for calculating the NDVI value.

Hint: In the 'ENVI' main menu [ENVI] use: <Basic Tools> <Band Math>.
In the 'Band Math' window under 'Enter an expression;' type: (float(b1) – b2)/(b1+b2) and click 'Ok'.
In the 'Variables to Bands Pairings' window highlight 'B1' and select Band 28 (803 nm) in the 'Available Bands List'.
In the 'Variables to Bands Pairings' window highlight 'B2' and select Band 17 (676 nm) in the 'Available Bands List'.
Specify the output path and filename (e.g. L1102rag10_Wh_cp_ndvi) and click 'Ok'.

Before the redundant pixels can be removed a NDVI threshold has to be defined. Pixels with a NDVI value below this threshold will be considered non-vegetation pixels and will be removed, i.e. masked out, in the hyperspectral image.

Action: Find out which threshold level should be used to mask out the non-vegetation pixels.

Hint: Load the newly created NDVI image in 'Display #2' and maximize as explained before.
In the 'Image' window use: <Tools> <Color Mapping> <Density Slice…>.
In the 'Density Slice Band Choice' select the newly created mask band and click 'OK'.
In the '#2 Density Slice' window click 'Clear Ranges'.
In the '#2 Density Slice' window use: <Options> <Add New Ranges…>
In the 'Add Density Slice Range> window set 'Range Start' to -1 and 'Range End' to 0.12 and click 'OK' & 'Apply'.

Question 10.2: You will now see a coloured region in the NDVI image. What do you think this coloured region represents in the real world? Change the ranges in the 'Density Slice' window by using <Edit Range>. Is the given range (-1 to 0.12) suitable to select the non-vegetation pixels? Check this by displaying the spectral profile for different pixels.

Hint: Make sure you have the coloured NDVI image on display #2 and the hyperspectral image on display #1. Link both images as follows: in the '#2 band Math' window use <Tools> <Link> <Link Displays …> and click 'OK'.
Now display the Z profile of the hyperspectral image in display #1. Notice that once the images are linked you have to move around the red zoom box to get the different pixel spectral profiles.

Once the NDVI range for non-vegetation pixels is defined, a mask can be generated. This mask is applied to the hyperspectral image by which the non-vegetation pixels can be removed.

Action: Create a non-vegetation mask and save this mask file temporary to memory.

Hint: In the 'ENVI' main menu [ENVI] use: <Basic Tools> <Masking> <Build Mask>.
In the 'Mask Definition Input Display' window click 'Display #2 (the hyperspectral image)'.
In the '#2 Mask Definition' window use: <Options> <Import Band Data Range…>.
In the 'Import Band Data Range' window set: 'Band Min Value' to -1 and 'Band Max Value' to 0.12. Make sure to set the 'selected band' to the band math image (it is not necessarily the default!).
In the '#2 Mask Definition' window use: <Options> <Selected Areas "Off">.
In the '#2 Mask Definition' window set the 'Memory' radio button and click 'OK'.

You have now created a mask file to select all vegetation pixels. This mask file is not saved to any file but temporary stored in memory. It will also appear in the 'Available Bands List' and you can visualize the mask. To try this, use Display #3 to load the mask you created.

Once the mask file is created it has to be applied to the hyperspectral image to remove all non-vegetation pixels.

Action: Use the generated mask to remove all non-vegetation pixels from the hyperspectral image (L1102rag10_Wh_cp). Save the result in a new file named L1102rag10_Wh_cp_mkd.

Hint: In the 'ENVI' main menu [ENVI] use: <Basic Tools> <Masking> <Apply Mask>.
In the 'Apply Mask Input File' dialog highlight the file 'L1102rag10_Wh_cp'.
Click <Select Mask Band> to open the 'Select Mask Input Band' window and highlight the 'Mask Band' created in 'memory1'. Click 'OK'.
In the 'Apply Mask Parameters' window use 'Choose' to specify the path and name for the masked result. Use filename L1102rag10_Wh_cp_mkd. Click 'OK'.

Selecting reference spectra

In this paragraph we will perform a supervised classification using the Spectral Angle Mapper classification tool which will use ground truth data collected during a field survey. Table 10.1 shows the geographical location in the Belgian Lambert 72 projection system of the different vegetation plots. The measured coordinates will be used to define Regions Of Interest (ROIs). ROIs are image pixels used to extract pixel spectra. To obtain a representative spectrum for each reference location we will define ROIs of 3 by 3 pixels. Because the pixel size is 1 m x1 m the defined ROIs of 3 by 3 pixels are within the observed field plot (5 m diameter).

Action: Close all windows and load the masked hyperspectral image L1102rag10_Wh_cp_mkd in Display #1 as explained before. Use the geographical locations listed in table 10.1 to define the different ROIs.

Hint: Load image 'L1102rag10_Wh_cp_mkd' in Display #1 by using the 'Available Bands List'. By right clicking the file name in the 'Available Band List' you can load true colour spectral bands by selecting <Load True Color>.
In the '#1 Image' window use: <Overlay> <Region of Interest…> to start up the Region Of Interest Tool.
In the '#1 Image' window use: <Tools> <Pixel Locator…>.
In the '#1 Pixel Locator' window use: <Options> <Map Coordinates>.
Enter the Eastern and Northern coordinates of the first location and click <Apply>.
In the '#1 Zoom' window enlarge the pixels, this can be done by clicking the + sign at the bottom left in the zoom window.

In the '#1 ROI Tool' window use: <ROI_Type> and click <Point>. You will select pixels in the zoom window so highlight the radio button 'window: zoom'.
In the '#1 Zoom' window first click the crosshair at the bottom left to select the central pixel and his eight neighbours.

You have now created your first ROI of 'Shrub', it measures 3 by 3 pixels and is coloured red. You can now add the other plots via the 'New Region' button in the 'ROI Tool'. Via the 'ROI Tool' you can edit each entry and change the name and colour of the corresponding vegetation type. You also can change the colour such that each vegetation type looks the same. Try this, colour all 'grass' types green, the 'dune vegetation' yellow and the 'shrubs' blue.

Defining all the ROIs for the locations in Table 10.1 is a time-consuming job. In file 'L1102rag10_Wh_Field' all the ROIs from the Table 10.1 are saved.

Action: Load the predefined ROIs from file'L1102rag10_Wh_Field' by using the ROI Tool.

Hint: n the '#1 ROI Tool' window use: <Options> <Delete All Regions>
In the '#1 ROI Tool' window use: <File> <Restore ROIs…> and select the file 'L1102rag10_Wh_Field'.

Question 10.3: Eleven ROIs are loaded for three different vegetation types. Each ROI contains 9 pixels. Why do you think three ROIs, one for each vegetation type, with each ROI containing only one pixel is insufficient?

You now have loaded eleven ROIs for three different vegetation types. Check the spectral variability by displaying the mean spectra for each ROI.

Action: Display the mean spectra for the different ROIs.

Hint: In the '#1 ROI Tool' window use: <Options> <Mean for All Regions>.
Right click in the 'ROI Means' window and click <Plot Key>.

Spectral Angle Mapper classification

Now you are ready to perform the Spectral Angle Mapper (SAM) classification. You don't have to tremble, it's not that difficult ☺.
You will use the mean spectra of the ROIs defined in the previous section to perform the classification. The Spectral Angle Mapper calculates a Rule image for each reference spectrum. The value of a Rule pixel represents the angle between the reference spectrum and the spectrum of the corresponding image pixel. A small Rule value means a small spectral angle between reference and input spectrum, indicating a similar shape of the spectra. Therefore the final class for a pixel is assigned to the smallest Rule value found.

Action: Perform a SAM classification by using the overlaid ROIs.

Hint: In the 'ENVI' main menu [ENVI] use: <Spectral> <Mapping Methods> <Spectral Angle Mapper>.
In the 'Classification input File' select the file 'L1102rag10_Wh_cp_mkd', click 'OK'.
In the 'Endmember Collection:SAM' window use: <Import> <from ROI from Input File…>.
In the 'Input Regions of Interest' window use: <Select All Items> & <OK>.
In the 'Endmember Collection:SAM' window use: <Apply>.
In the 'Spectral Angle Mapper Parameters' window: set the <None> radio button, specify the 'Output Class Filename' (i.e. L1102rag10_Wh_cp_mkd_Cl) and the 'Output Rule Filename' (i.e. L1102rag10_Wh_cp_mkd_R) & <OK>.

The Spectral Angle Mapper Classifier will take some time. Depending on the speed of your computer, 5 sec to 1 min. The results, the classified image and the Rule image, are available in the 'Available Bands List' for loading.

You can load the classified image in 'Display #2' and the Rule image in 'Display #3' and link both with the image in Display #1 (use Display #1 as reference).

Question 10.4: Use the 'Pixel Locator' to locate the pixel at Sample:558 and Line: 311. To which class is this pixel assigned. Try to find out what the minimum Rule value is. To which class should this pixel belong. Compare with the classified image. Is the pixel classified correctly in L1102rag10_Wh_cp_mkd_Cl?

Accuracy assessment

Checking the accuracy of the SAM classification can easily be done using ENVI.

Action: Check the accuracy of the SAM classification.

Hint: In the 'ENVI' main menu [ENVI] use: <Classification> <Post Classification> <Confusion Matrix> <Using Ground Truth ROIs>.
In the 'Classification Input File' select the classified result 'L1102rag10_Wh_cp_mkd_CL' & <OK>.
In the 'Match Classes Parameters' use: <OK>.
In the 'Confusion Matrix Parameters' use: <OK>.

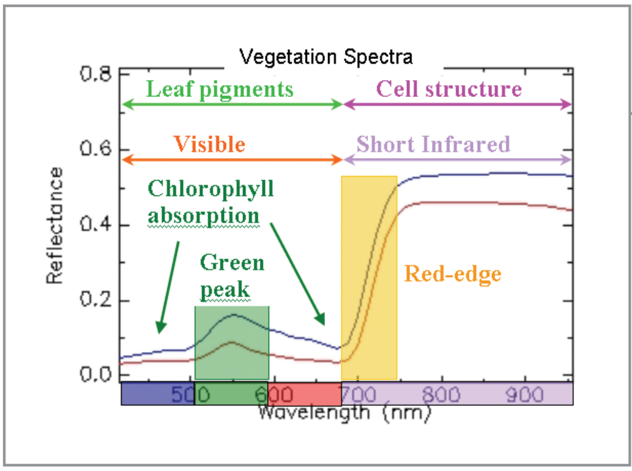
It can easily be seen in the 'Class Confusion Matrix' that the overall accuracy equals 80% with Kappa Coefficient equal 0.78.

Question 10.5: How many pixels in the 1st grass ROI (Ground Truth) are correctly classified? The confusion matrix is saved as 'conf_matrix.txt'.

Answers to questions

Answer 10.1.: How can you distinguish vegetation spectra from non-vegetation spectra? In other words, how does a typical vegetation spectrum looks like?

Vegetation spectra can easily be distinguished from non-vegetation spectra by some characteristic features. Absorption by green plants is strongest in the blue and red part of the visible spectrum. The green part of the spectrum is less absorbed and this is the reason why plants look green to the human eye. This increased reflection in the green area around 550 nm is called the green peak and is one of the two characteristic spectral features for vegetation.
The energy contents of the non-visible short infrared is insufficient for photochemical reactions and therefore it is not absorbed by the chlorophyll and the other leaf pigments. This results in a strong increase of reflection around 690 nm called the 'Red-edge' which is typical for vegetation and is the second characteristic spectral feature for vegetation. These typical features are illustrated in Figure 10.1.



>> Figure 10.1: Vegetation spectra are characterized by two typical spectral features; the green peak and the red-edge.

Answer 10.2.: You will now see a coloured region in the NDVI image. What do you think this coloured region represents in the real world?

It looks like all non-vegetation pixels (water and sand) are coloured red. Using the 'Density Slice' option it is possible to colour a certain NDVI range. By checking the corresponding spectral profiles in the linked hyperspectral image, it is possible to decide on the optimal threshold level for vegetation/non-vegetation selection. As was already mentioned, the non-vegetation range is situated in the NDVI range between -1 and 0.12. This method for vegetation/non-vegetation selection is empirical, but is suitable for this purpose.

Answer 10.3.: Why do you think three ROIs, one for each vegetation type, with each ROI containing only one pixel is insufficient?

There is a lot of variability in the hyperspectral imagery. Pixels are not always pure, most of the time pixels are a mixture of reflectance from green leaves, soil, etc. Identical spectral signatures in the same hyperspectral image are not realistic and therefore choosing only one pixel spectrum as a reference is not advisable. The geographical positions measured during the field survey are located in a homogenous area with a diameter of at least 5 m. Choosing a ROI of 3 by 3 pixels (when the pixel resolution is 1 m x 1 m), will result in a ROI within the homogenous region. The final ROI spectrum for this particular ROI will be the average of these nine pixels, resulting in a spectrum which is more representative for this particular vegetation type. By defining several ROIs for each vegetation type, the variability between individuals within the same vegetation type will be covered.