Spectral Unmixing Exercise

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Objective

The overall objective of this exercise is to use Sentinel-2 (S2) data to estimate the surface cover abundances for a city using Spectral Unmixing. The individual learning objectives include you getting familiar with

- Sentinel-2 MultiSpectral Instrument (MSI) data
- the SNAP Sentinel-2 toolbox and its tools
- the theory of spectral unmixing
- the application of spectral unmixing

General Instructions

This is a team exercise. You will be assigned to a group and you will do the exercise along with your fellows in your group. You will prepare a very short presentation on your results, their interpretation and any thoughts at all. One of you will present your findings on Thursday afternoon. Your overall presentation needs to be **5 minutes** in duration.

Data

Here are the data you will use and where you can find them in the computer.

Sentinel-2 MSI Level 1C product
C:\SU\S2A_OPER_PRD_MSIL1C_PDMC_20151218T191212_R122_V20151218T101215_20151218T101215.SAFE

Reference Dataset
C:\SU\ReferenceDataset

Here is also an intermediate product for you to use in case something goes wrong with your calculations. These are

Sentinel-2 MSI Level 2A product
C:\SU\S2A_USER_PRD_MSIL2A_PDMC_20151218T191212_R122_V20151218T101215_20151218T101215.SAFE

Exercise

Follow the instructions below to perform spectral unmixing for Rome and try to reply to the given questions using also graphs, figures, images etc. Put your answers, findings and any observation at all in your presentation. You will be given 5' to present your findings.

Introduction

1. Listen to the theory of Spectral Unmixing from the short presentation. You can read more in Keshava & Mustard (2002).

Sentinel-2 is a polar-orbiting, multispectral high-resolution imaging mission for land monitoring. It carries a MultiSpectral Instrument (MSI) covering the electromagnetic spectrum from the visible to the shortwave infrared with a pixel resolution from 10 m to 60 m. Two satellites in orbit will provide data at a five days interval at the equator. Sentinel-2 combines a large swath, frequent revisit, and systematic acquisition of all land surfaces at high-spatial resolution and with a large number of spectral bands (Drusch et al., 2012).

2. Visit the Sentinel-2 user guide from https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi;jsessionid=9628F269E8D4CE914C59DE469CCB9103.jvm1 to review the Sentinel-2 characteristics, the available products and the MSI spectral bands.

A. Which bands of Sentinel-2 MSI do you think are more suitable for mapping the cities? Which S2 product would you use? In what spatial resolution?

Data Preprocessing

3. Download the Sentinel-2 scene corresponding to 18 December 2015 from the ESA Hub https://scihub.copernicus.eu/s2/
4. Open it in SNAP and use Sen2Cor to atmospherically correct the tile corresponding to the city of Rome in 20 m spatial resolution.
   4.1. Remove from the product all the tiles you don't need (just delete them)
   4.2. Open a command line and type
   `L2A_Process --resolution 20 [Dir/ProductName]`
5. Keep your selected bands in both products, using *Subset* to proceed with spectral unmixing

Endmembers Selection

The endmember collection is a very important procedure in spectral unmixing. The quality and quantity of the endmembers impacts the final result.

6. Visualize RGB composites of L1C and L2A products using synchronized views and cursors to search for endmembers
7. Use the *Spectrum View* tool to view the spectra of different surfaces (pixels) in the different products.

B. Apart from visual inspection of our image, what other means can we use to ensure the quality of an endmember?

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8. Collect representative endmembers corresponding to the following surface cover types:
   BuiltUp, Vegetation, Soil, Water
   Use *pins* to collect and name the spectra. You will find this tutorial video useful https://www.youtube.com/watch?v=5znAQH6vrLs.
9. Use the *Spectrum View* tool to save your endmemember spectra in a .csv file.

Perform Spectral Unmixing

10. Use your collected endmembers in different combinations to perform spectral unmixing
    - without constraints
    - with the sum-to-one constraint
    - fully constrained

For more information on how to run the spectral unmixing read the SNAP help.

11. Visualize your results in all cases. You can use an RGB composite, for example
    R: BuiltUp, G: Vegetation, B: Water

What is black in your image (no color assigned) corresponds to Soil.

C. What does the value of a pixel represents in your results? Are all your results meaningful?

Errors Analysis

12. Visualize the error bands and their histograms.
13. Use the synchronized views to see where you are having the larger errors.

D. What do the error bands stand for? Where do you notice the larger errors? How can you use this information to improve your results?

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14. Refine your results wherever that is needed. “Remove” the values greater than 1 or lower than 0, using Band Math.
15. Try to combine your results from different runs, to achieve better accuracy in your results.

E. What are the assumptions behind the spectral unmixing? Can you propose any advances to overcome any of the assumptions?

Validation

You can use the Reference Dataset to validate your results. The Reference Dataset is composed of Built-up, Vegetation, Soil and Water surface abundances estimated in for each Sentinel-2 pixel from a higher resolution land cover classification map. It only covers a small area of Rome.

16. Use the Reference Dataset to evaluate your result. You will need to use *Collocation* to collocate the Reference Dataset with your result to proceed to *Band Math*. Estimate the difference of your dataset with the reference and see the histograms.

F. What are the main issues when performing spectral unmixing for cities? What are the advantages of using Sentinel-2 images?

References

Drusch, M., Del Bello, U., Carlier, S., Colin, O., Fernandez, V., Gascon, F., … Bargellini, P. (2012). Sentinel-2: ESA’s Optical High-Resolution Mission for GMES Operational Services. *Remote Sensing of Environment*, *120*, 25–36. http://doi.org/10.1016/j.rse.2011.11.026

Keshava, N., & Mustard, J. F. (2002). Spectral unmixing. *Signal Processing Magazine, IEEE*, *19*(1), 44–57.