Test Image to Validate the Performance of Endmember Extraction and Hyperspectral Unmixing Algorithms

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ABSTRACT

The main objective of this work is the generation of a test image that will allow us to validate endmember selection methods and Hyperspectral unmixing algorithms The proposed ground work consists of:

Delimitation and measurement of these endmembers with automatic methods, obtaining their hyperspectral signature using both ground spectroscopic measurement and sensor measurement. Measurement of extent of each endmember on the scene using GPS. Coordinates measurement of Ground Control Points scattered on the scene. The abundance ground truth image is generated counting classified pixels on the high resolution image. The different errors and problems introduced by registration are evaluated. Finally a new technique based on target detection is discussed.

Keywords: Hyperspectral unmixing, endmember extraction, ground truth image, geo-registration.

1 INTRODUCTION

Remote sensing has traditionally been focused on the development of thematic maps obtained as a result of classification processes. Classification algorithms applied to low spectral resolution images are usually validated using ground truth images that only indicate the existence of a certain cover at the location of each pixel.

The evolution of airborne imaging spectrometers has provided us with remote sensing instruments with very high spatial, radiometric and spectral resolutions [1]. During the last years, several algorithms to extract endmembers and/or calculate their abundance in a hyperspectral image have been proposed in the literature[2], [3], [4], [5]. Validation of these methodologies must be made with the support of a ground truth image. It would be of great interest for us to obtain a test image with information of the abundances of elements at each pixel, in order to compare the results provided by different hyperspectral unmixing methods.

1.1. Planned Ground Truth Data

We intend to obtain a hyperspectral image with ground truth information about the abundance of end members at each pixel. Since this requires a considerable amount of ground measurements, we have selected a location relatively close to our research institute in the South-western area of Spain. During the projected flight period (june-july 2001), the selected area (Dehesa agro forestry and pasture ecosystem) presents favorable climatic conditions, allowing the discrimination between species.

1.2 Anticipated Results of the Research.

The possibility of having a test image acquired by DAIS sensor with ground truth information about endmember abundances may encourage the scientific community to use this image as a unique or

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complementary reference in the validation of any new algorithm focused on endmember extraction or hyperspectral unmixing.

2. OBJECTIVES AND SIGNIFICANT ASPECTS

2.1. Detailed Objectives

The main objective of our work is the generation of a test image that will allow us to validate endmember selection methods and Hyperspectral unmixing algorithms [6]. In order to achieve this general objective, we propose the following specific tasks:

i) Determine the endmembers (spectrally pure elements) present in a scene using AMEE [5].
ii) Classify the high resolution image from the endmember obtained in the previous phase.[7]
iii) Obtain the abundance vector w at each pixel of the low resolution image counting the classified pixels, and using information directly obtained from the scene.
iv) Generate a ground truth image associated to each endmember containing the abundance of the endmember at each pixel.

Different altitude flight lines will produce data with different GIFOV, using the high resolution image we obtain a ground truth map with considerably higher spatial resolution than the others available on the platform sensor [8], (each pixel of a low resolution image correspond to a various of the high resolution image).
The classification of the high resolution image, offer us various classified pixel for every pixel in the low resolution image these pixels are used to build the ground truth image using the following steps:

- Find the group of pixels in the high resolution image associated with each pixel in the low resolution one.
- Counting the number of pixels classified as belonging to each class in the group we obtain the abundance for this class in the low resolution image.
- Build a low resolution ground truth image using the abundance for each endmember at each pixel.
- Ground truth campaign will provide us with the necessary information to measure the exact location (obtaining by GPS the contour of each target) and the spectral signature of the target in different observation conditions (measured with a ground spectrometer located in one high adjustable platform).

2.2 Site

The studied zone is the public property called “El Cuartillo” placed nearby the Carretera Nacional 521 Trujillo-Portugal for Valencia de Alcántara.
The reasons for choosing this area are the following:

- It is near out laboratories.
- It can be easily reached.
- Public property.
- State ecosystem with a low oaks density.
- It includes some ponds that can be used as a spectral reference.
- It includes tennis and sports courts that can be easily placed for the image registering.
- Precise cartographic information available due to its nearness to Cáceres.
- A big amount of images available, as a result of flight campaigns promoted by our university.

This zone is in the Time Area 29, Strip S, a Hundred Kilometres Grid QD, of the U.T.M. projection Sheet nº 11-28 of the Spanish Mapa Topográfico Nacional of the Servicio Geográfico del Ejército of the series L 1/50.000.
A “dehesa” sub-scene has been selected on the low altitude ROSIS image (cas-2806-1-03.ag).
Dehesa can be defined as an agro forestry and pasture agro_ecosystem which extends itself over the west, south-west and central parts of the Peninsula. The general characteristic that defines dehesa is the presence of pasture and a low density tree canopy, typical dehesa trees are Quercus, (Quercus ilex (Encina) and Quercus suber (Alcornoque), quercus trees are clearly different to soil and other canopy, easy to identify, count and measure, dehesa is a stable ecosystem without significant changes over the years.

In this sub-scene can be easily distinguished the closure, a road and some trees (oaks), the vegetable layer is formed by pasture, oaks, ponds and some eucalyptus.

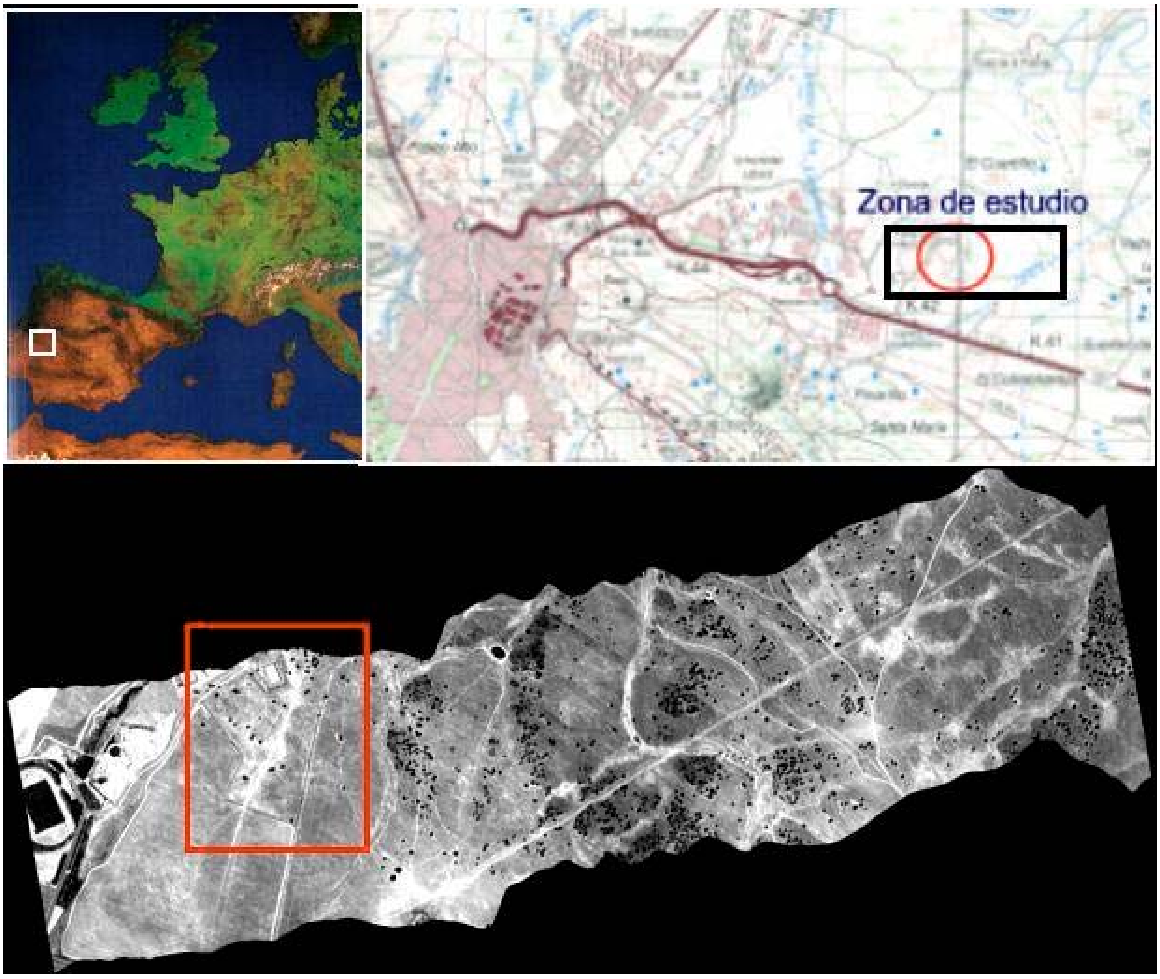


Fig 1 Site on Iberian peninsula, Spanish cartography and ROSIS image.

The figure 1 show the scene location on the Iberian peninsula, Cáceres cartography and DAIS image.

2.4 Images.

2.4.1 HYSENS images.

Two flights, at different altitude, have been made the same day (28-06-2001) to carry out this study (HYSENS 2001 ES-4 project), in each one of them two sensors, DAIS 7915 and ROSIS have been used simultaneously.

Hysens 2001 – DAIS 7915 images

ES4-01 (CACERES) File: ES_4_1_geoatm_west, (1940 m a.g.) ∅ GIFOV 3.0 m

ES4-02 (CACERES) File: ES_4_2_geoatm_west, (3660 m a.g.) ∅GIFOV 5.0 m

Hysens 2001 – ROSIS images.

ES4-01 (CACERES 1) ROSISHR, cas_2806_1_03_geoatm, (1940 m a.g.), sub-scene 03∅ GIFOV 1,2 m

ES4-01 (CACERES 2) ROSISLR, cas_2806_2_01_geoatm, (3660 m a.g.) , sub-scene 01∅ GIFOV 2.4 m

These images are available in http://grnps.unex.es/index2.html

Therefore, considering a grid unit of 0.2*0.2m the pixels in the four images will contain a integer number of elements of this grid.
The image with a worst resolution GIFOV 5*5 will have a pixel corresponding to 625 (25*25) of such elementary pixels.

The image GIFOV 3*3 will have a pixel corresponding to 225 (15*15) of these grids.
The image GIFOV 2.4*2.4 will have a pixel corresponding to 144 (12*12) of these grids.
The image GIFOV 1.2*1.2 will have a pixel corresponding to 36 (6*6) of these grids.

In figure 2 it can be observed the relative size of each one of these pixels over the grid formed by elementary pixels, considering an ideal situation in which the pixels are perfectly aligned.

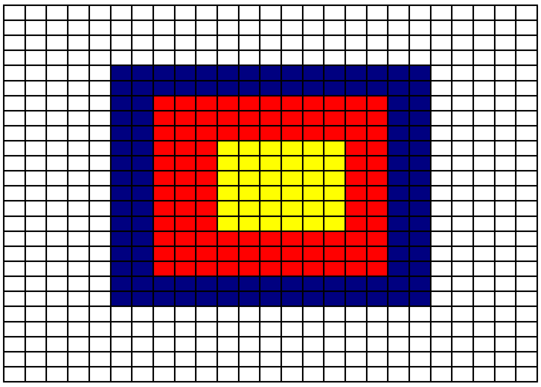


Figure 2 Comparison between the pixels used in the four images and the minimum grid unit of 0.2*0.2m

2.3.4 Other Images.

Figure 3(a). City cartography with GCP labels, 3(b). Metric camera case.

Other images have been used in the project:

1. Official cartography of the Excelentísimo Ayutamiento de Cáceres. (fig 3a).
2. A pair of metric camera images scale 1/20.000 focal 154,053mm date 19-1-2001, 13h57’

for the generation of a digital elevation model and for the detection of geometric errors (fig 3b).

3. PROJECT DEVELOPMENT.

In order to minimize the geometrical errors between images obtained with different sensors and flight lines we perform a ground campaign to collect hyperspectral signatures and targets position. One additional registration of the images has been performed using these control points (the same points for the four sub-scene images).

3.1 Ground campaign.

A exhaustive ground campaign was performed in order to acquire exact GPS position of each region of interest (ROI) on the scene:

- Oak tree (measuring the perimeter with 8 points)
- Nude soil (measuring the perimeter)
- Pasture zones.

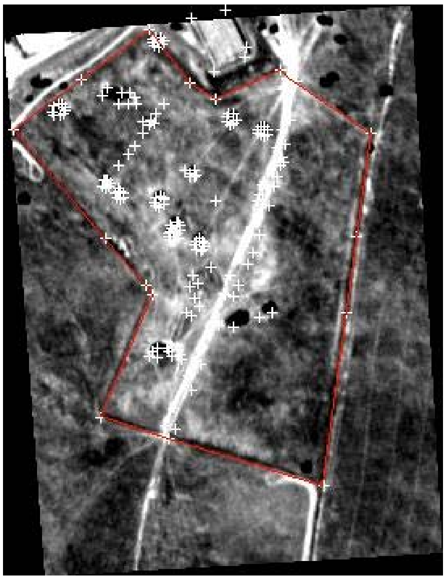
For each ROI 3 spectral measurement were done for each oak tree from a crane using ASD spectro-radiometer, figure 3 show some pictures of this campaign.

Figure 3. Ground Campaign.

3.2 Image registration

We have had to solve a registration problem with the ROSIS image because the geo-reference coordinates did not match the ones in the Mapa Topográfico Nacional that we are using (left upper corner 728.000,4375.000).

In order to check the coordinates that appear in the four images with the town cartography, we have placed the GCP that are easy placed in the image, as they are shown in figure 3(a). This additional registration produce a reasonable correspondence with the city cartography figure 4(a), similar results are obtained for the other images .The position of the GCP points measured in the ground campaign with GPS and the registered ROSIS high resolution image sub-scene is show in figure 4b.



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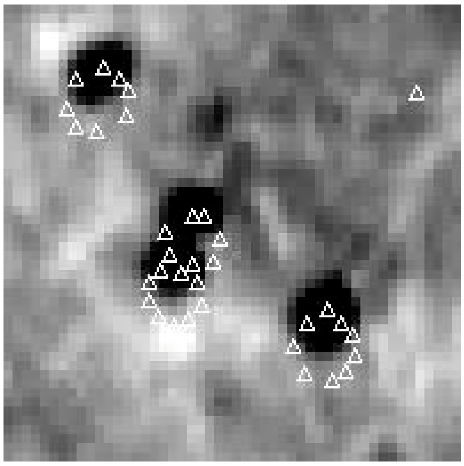


Figure 4 (a) ROSIS image with superimposed cartography 4 (b) ROSIS zoom image with oak tree GCP's measured by GPS.

When you observe a zoom of this image some spatial errors are obvious, and they make impossible the use of the space data to compare sub-pixel results from different images, specially when such images come from different sensors and they have suffered different correction methods.

To solve this problem we have tried two different solutions:

a) Comparison of the geo-corrected DAIS-ROSIS images and the ground truth image using spatial profiles obtained from the center of one oak tree to the center of other tree, when these trees can be easily located on the images.
b) Use the center of each oak tree as coordinates origin in order to minimize the positioning errors.

The method comprises the following steps:

1. The 20 first and last band of the spectrum were eliminated in order to reduce noise
2. Endmembers for quercus, soil and pasture are extracted from the ROSIS high resolution image ROSISHR using the AMEE algorithm.
3. SAM ROSISHR image classification with the endmembers obtained in (2) .
4. Resize the classified ROSISHR image to obtain a grid unit of 0.2*0.2m (figure2).
5. Counting the number of pixels classified as belonging to each class in the neighborhood of each pixel we obtain the abundance for this endmember in this image. (consider as neighbor the pixel comprised in the grid unit of the ROSISHR image that is inside the low resolution image grid)

4 RESULTS.

Applying the above described method (a) to the ROSISHR image we obtain the AMEE endmembers shown in Figure 5 the spectral signature obtained for these endmembers can be easily assigned to:

1. Nude soil (blue in the map)
2. Dry pasture (red in the map)
3. Evergreen –oak. Trees. (green in the map)

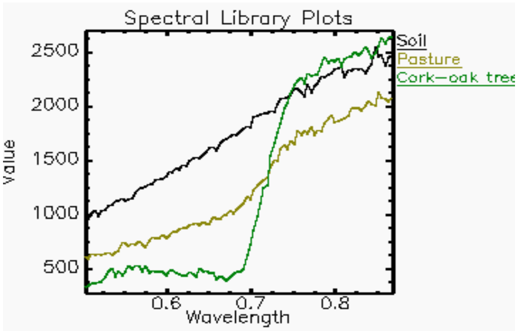
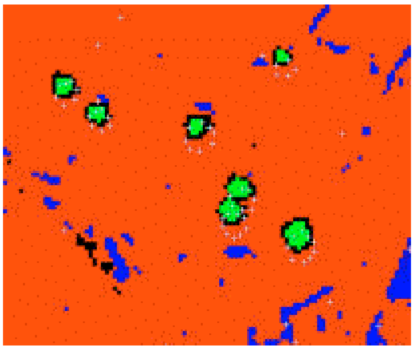


Figure 5. AMEE endmembers spectral signature for high resolution ROSIS sub-image.

Applying SAM classification method to ROSISHR image we obtain the image shows in figure 6 (a). Each pixel in the low resolution image contains 4 neighbor pixels of the (1.2x1.2) image, counting the proportion of pixels from each endmember in this neighborhood, we estimate the abundance image show in 6(c) .



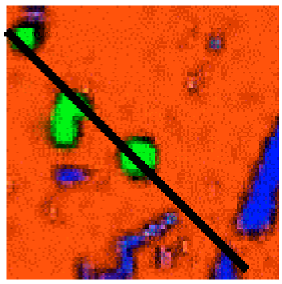
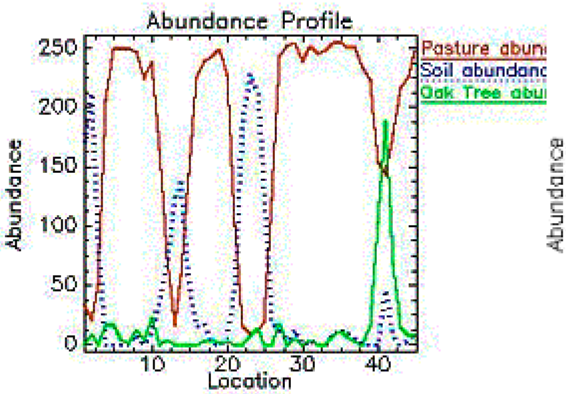


Figure 6(b) Estimated abundance image obtained counting pixel, include profile line.

Figure 6 (a) ROSIS-HR image SAM clasification with oak trees GCP's

The position errors between different images can be minimized to compare the results obtained by sub pixel algorithms using points easily to located in the image and visualizing the abundances profiles across the lines of these images obtained using these points; figure 7 (a) shows the abundance profile for figure 6(b) and figure 7(b) shows the same profile for the LSU image obtained from the ROSIS LR image using the endmembers shown in figure 5.



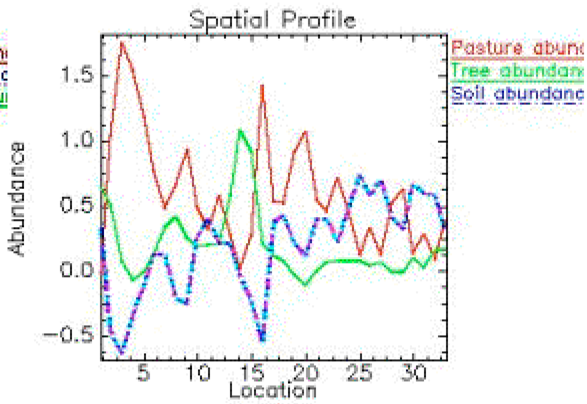
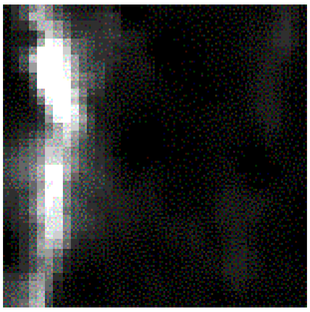


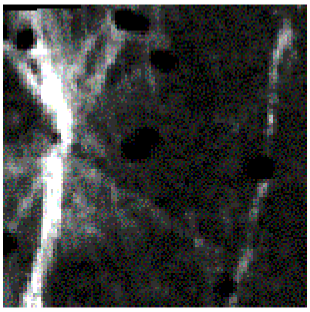
Figure 7 (a) Estimated abundance of AMEE endmembers across the line show in figure 6(b)

Figure 7 (b) LSU abundance of AMEE endmembers in ROSISLR image across the line show in figure 6(b)

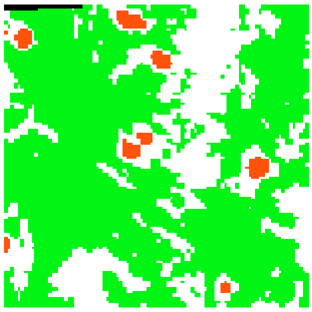
The second methodology (b) uses coordinates centered in one oak tree in order to minimize geometric error, figure 8 shown the abundance maps obtained with the AMEE endmembers around the central tree, and the RMSE error.



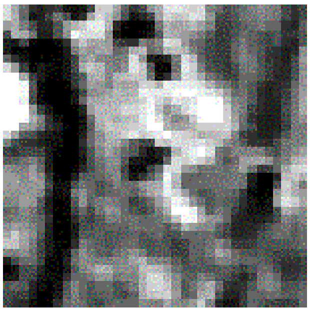
8 (a) DAIS HR sub image (pixel size: 3x3)



8(b) ROSIS HR sub image (pixel size: 1.2x1.2)

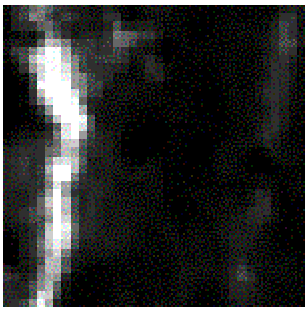


8(c) SAM applied over ROSIS High resolution (pixel size: 1.2x1.2)



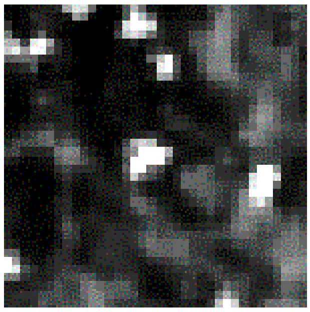
8(d) DAIS High resolution abundance maps (pixel size: 3x3)

RMSE Error: 0.382503



8(e) DAIS High resolution abundance maps (pixel size: 3x3)

RMSE Error: 0.299565



8(f) DAIS High resolution abundance maps (pixel size 3x3)

RMSE Error: 0.562648

4 CONCLUSIONS.

There is a series of problems that make difficult to generate a ground truth image from the geo-referenced ground measurements, or from an image with a better space resolution.

The GIFOV centers do not match, the problems are minimum between the images taken in the same flight, due to the fact that the acquisition geometry is the same, these distortion problems are caused by the sensor movements.

These problems are usually corrected by geo-referencing the image, assigning their geographic coordinates to each one of the points in the image, which solves the problem of placing the same point in the different images in a satisfactory way in grayscale and multi-spectral images.

The introduction of the geographic grid in the image produces problems of non-correspondence between the geographic and the image grid, these problems are solved by the interpolation or convolution of the values corresponding to the nearest pixels, the problem is that they cause an average effect on the hyperspectral signatures that conditions the unmixing results.

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