Tecnologie e Metodi Avanzati per il Recupero e il Riciclo dei Materiali

5° Seminario Lunedi 7 Maggio 2007

Tecniche di rilevamento e logiche di selezione mediante procedure di imaging iperspettrale

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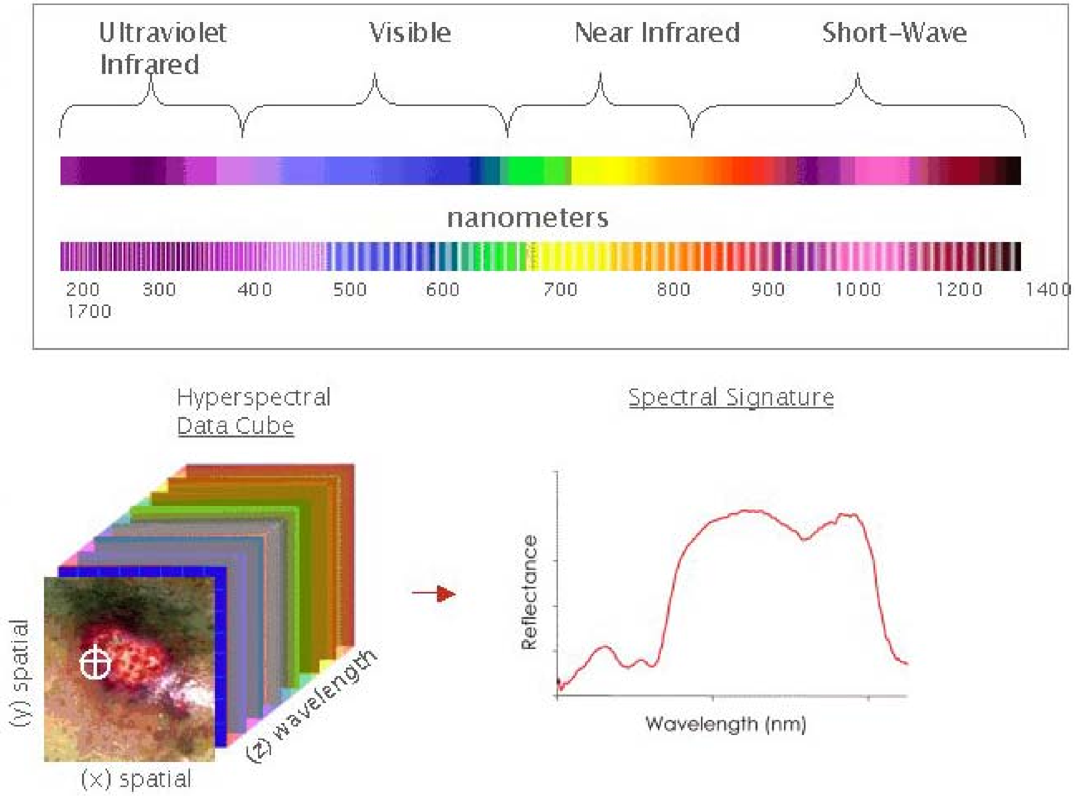
Introduction

What is hyperspectral imaging



Hyperspectral imaging is an emerging technology developed in recent years with many potential applications as inspection tool at industrial scale. It combines the advantages of spectroscopy and imaging techniques.

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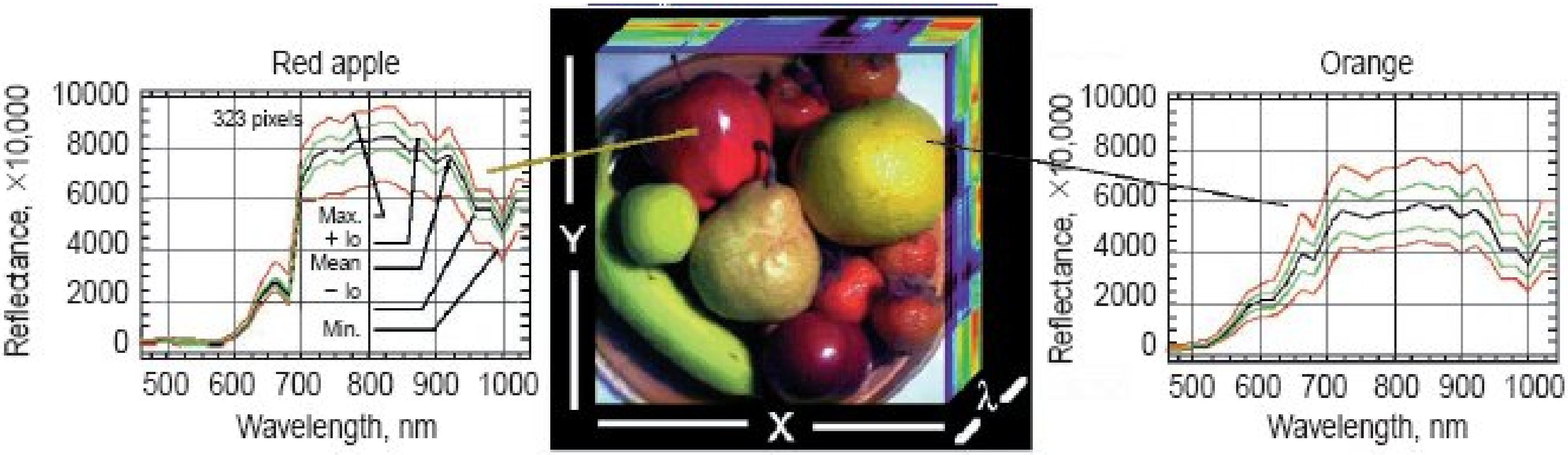
The image cube



The data product or output of a hyperspectral sensor is a stack of images of a scene, or a sample, acquired in contiguous bands over a spectral range and it is often referred to as the “*image cube*”. This cube has two spatial dimensions and the third dimension is wavelength. The system in addition to spatial information provides spectral information in a wide range of wavelength for each pixel of the image.

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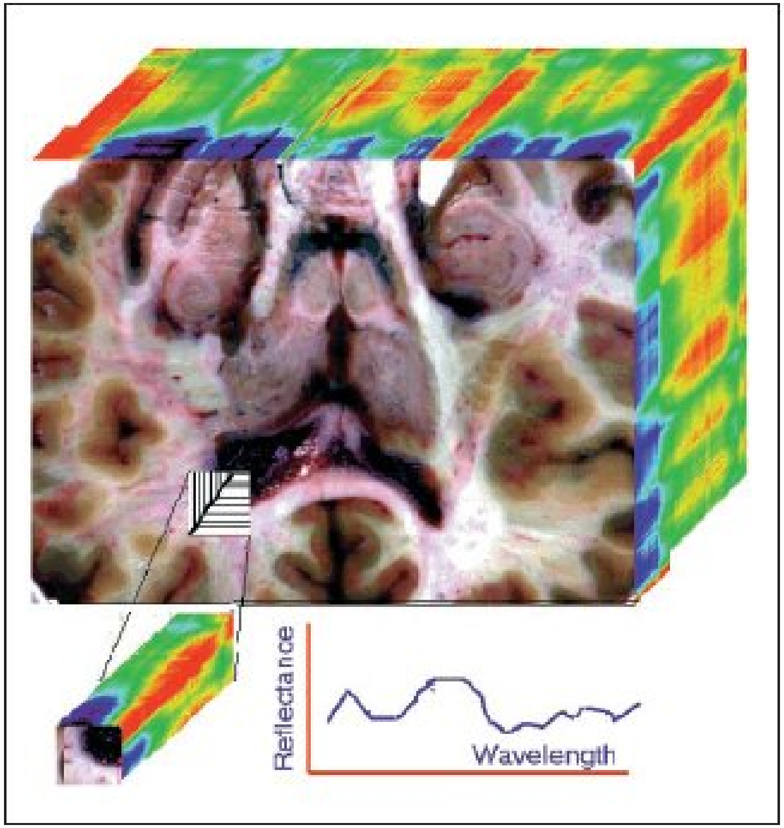
Why hyperspectral imaging?



Brain activity mapping using hyperspectral imaging. Data courtesy of Drs. G. Bearman of JPL and A. Toga of UCLA.

It is sometimes necessary to analyze and establish the local distribution of properties of interest in a sample that is spatially nonhomogeneous. With conventional spectroscopy one can either tediously scan the entire sample with a focused optical probe or obtain average properties over the entire sample using a single measurement.

This is where hyperspectral imaging may prove useful.

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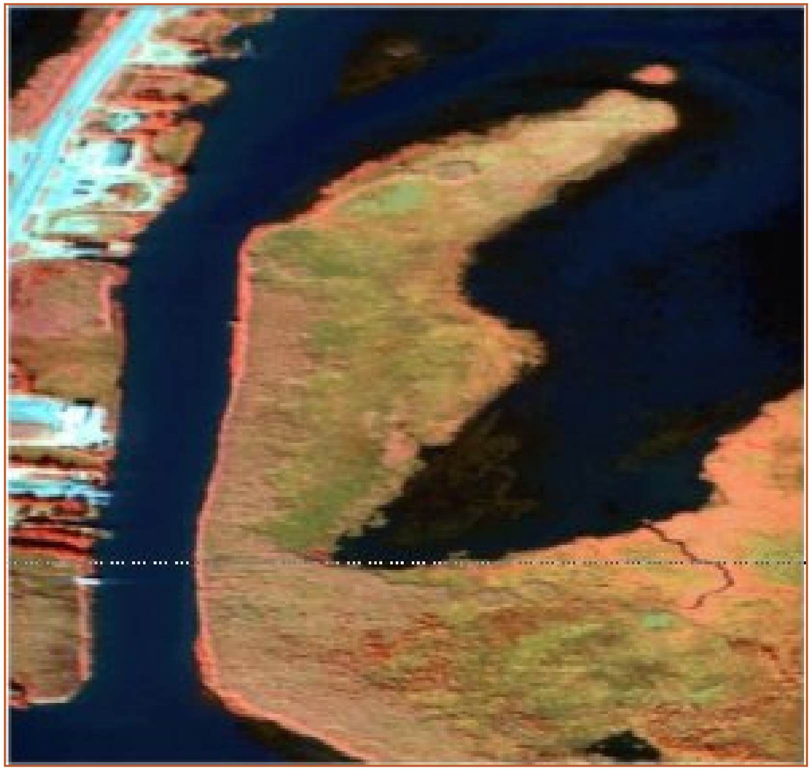
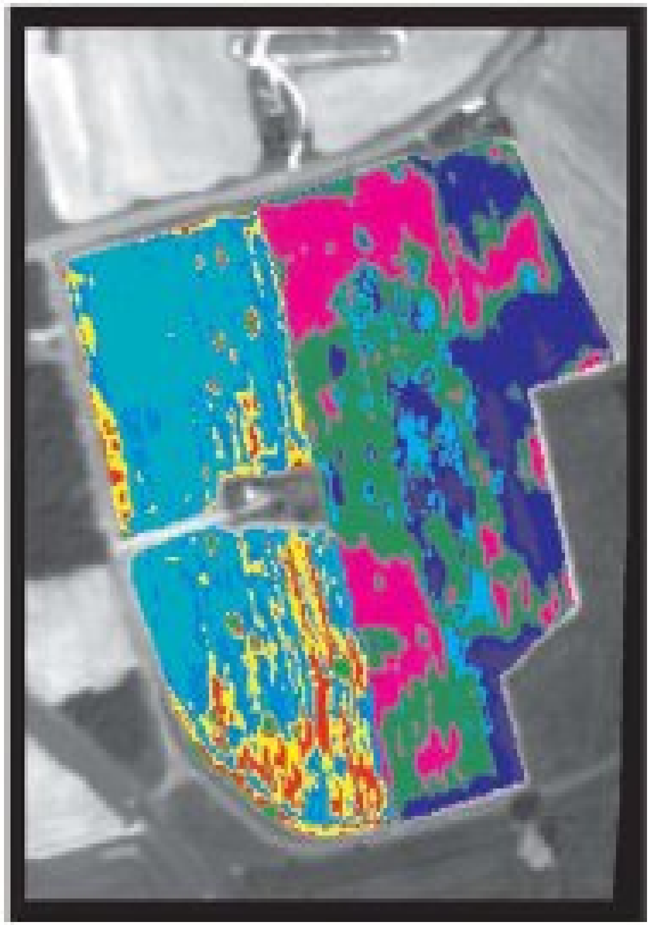
Brief hystorical background



The birth of multispectral imaging

In the early 1960s satellites started circling and acquiring photographs of Earth, and imaging became a tool for many Earth studies. The gray level in a B&W image indicates differences in optical properties and thus lends itself for differentiation of materials. Imaging the Earth through several carefully selected color filters greatly enhanced the identification of different objects. LANDSAT SATELLITES gave images in seven wavelengths bands.

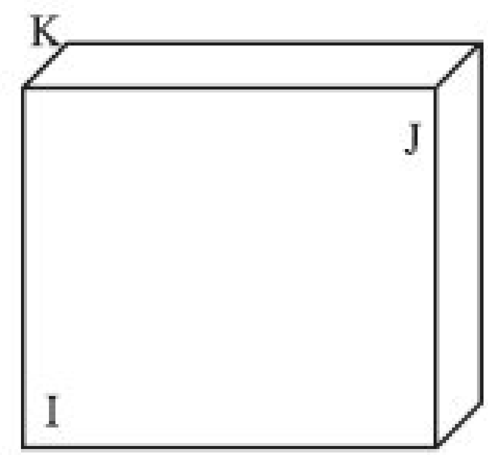
Brief hystorical background



The birth of hyperspectral imaging

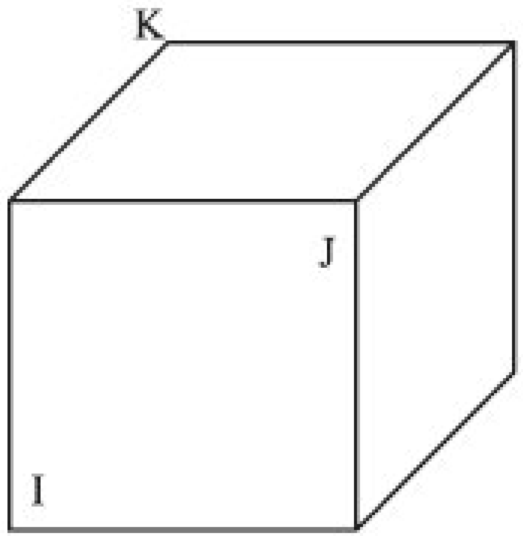
Since multispectral imaging in a handful of broad noncontiguous spectral bands facilitated better understanding of our environment, why do not extend this concept to a few hundred narrow bands? Thus spectroscopy for remote sensing, or hyperspectral imaging, was born in the early 1980s with the Airborne Imaging Spectrometer and later on with the Advanced Visible and InfraRed Imaging Spectrometer (AVIRIS), both at NASA.

Multispectral and hyperspectral



Multispectral image

K<< I ≈ J



Hyperspectral image

K ≈ I ≈ J

Typical multispectral and hyperspectral images are characterized by *I* rows and *J* columns measured for *K* variables (as wavelengths). In hyperspectral images the number of variables is of the same order as the number of rows or columns.

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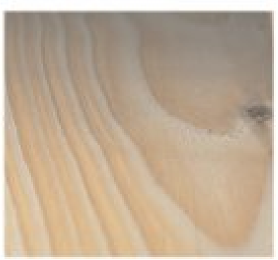
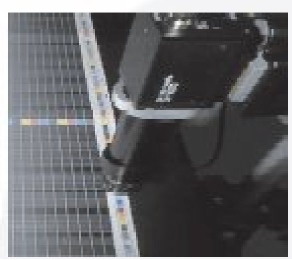
Hyperspectral imaging application

Hyperspectral imaging has now moved out of satellites and airplanes into laboratories.





Applications include on-line inspection at industrial scale in different sectors, such as food, glass, plastic, cosmetic, wood, textile, leather, ceramic tile, etc.

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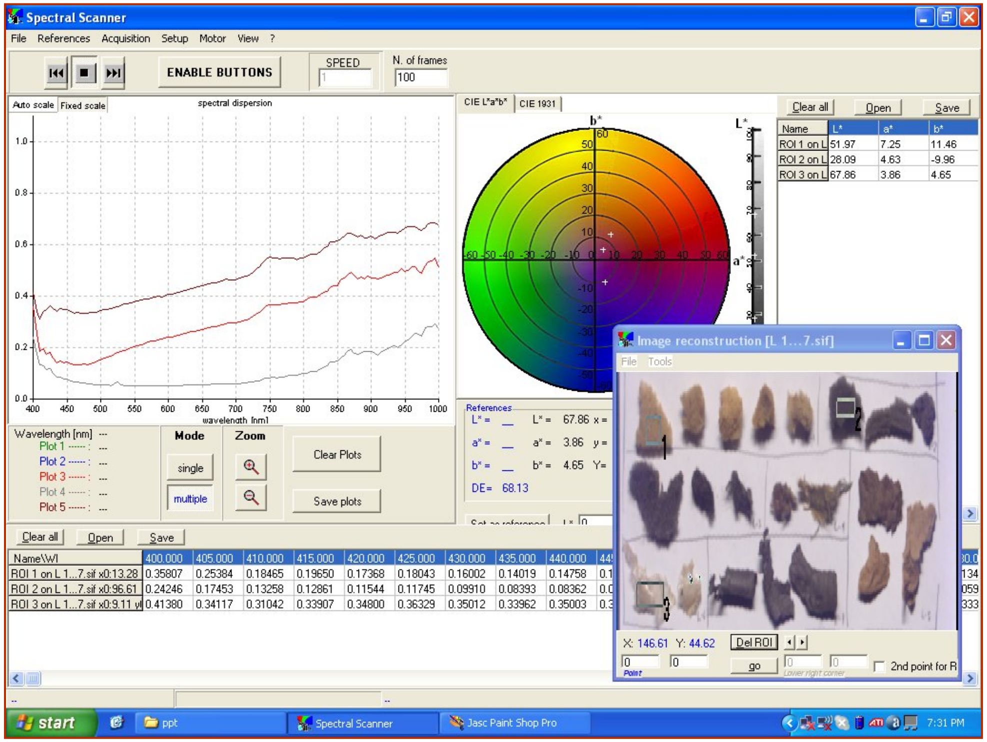
Data handling and processing

Hyperspectral images are very large files (usually from ten to hundred Mbytes).

Handling, displaying, visualizing and processing such files requires efficient programming tools.

The algorithms used for analysis are variations on the common chemometric tools used in conventional spectroscopy. Many general purpose analytical techniques use statistical tools such as principal component analysis.



Control Panel of Utilized Software

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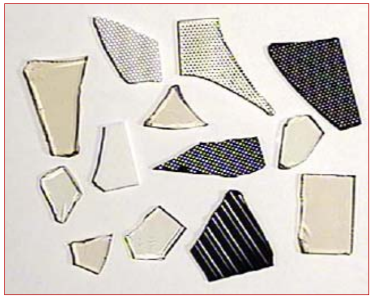
Hyperspectral imaging

Particle systems characterization

This technique has many potential applications in particle systems characterization, when recognition of particles of different nature and composition or different portions of inhomogeneous particles is required. In fact, particles of different nature will present different spectral signature in different spectral ranges.

In solid waste recycling, using such technique it is possible to develop low cost on-line inspection/control systems to be implemented at industrial level.



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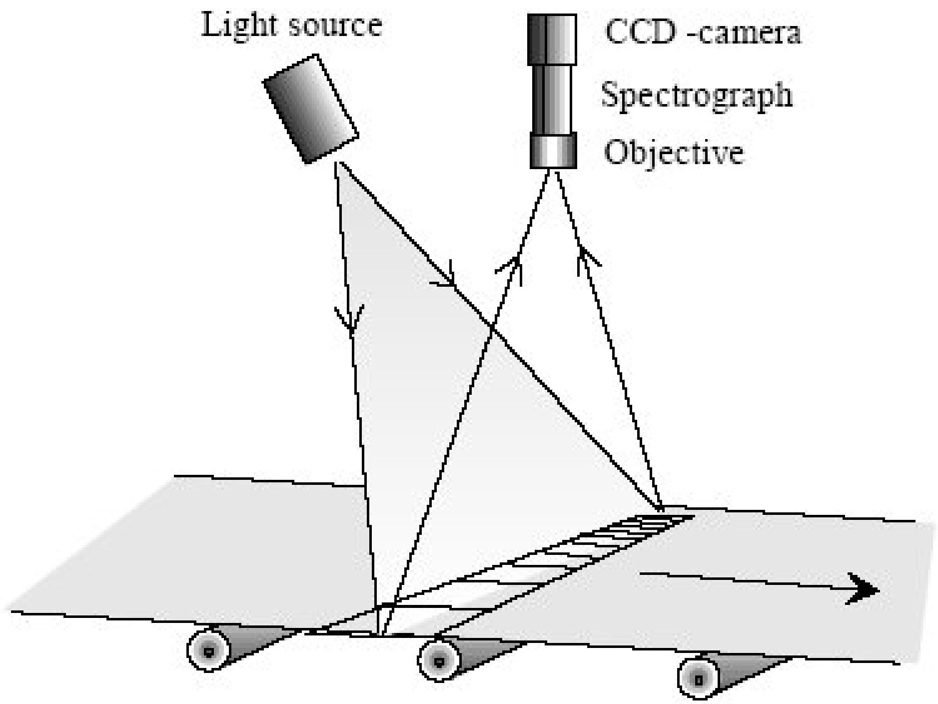
Architecture set-up



Architecture Set-Up

Hyperspectral imaging is based on the utilization of an integrated hardware and software architecture able to digitally capture and handle spectra, as an image sequence as they result on a surface sample properly energized.

The detection system is constituted by four basic elements:

- The optic
- The spectrograph
- The CCD camera
- The light source

Equipment

Different equipment are available, working in different wavelength spectral ranges:

- ***ImSpector™*** **V7 (Specim) working in the visible field (400-700 *nm*);**
- ***ImSpector™*** **V10 (Specim) working in the visible-near infrared field (400-1000 *nm*);**
- ***ImSpector™*** **N17 (Specim) working in the near infrared field (1000-1700 *nm*);**
- ***ImSpector™*** **N25 (Specim) working in the visible field (1000-2500 *nm*);**

ImSpector **is an imaging spectrograph, designed for both industrial and research use, capable of simultaneously measuring the optical spectrum components and the spatial location of an object surface.**

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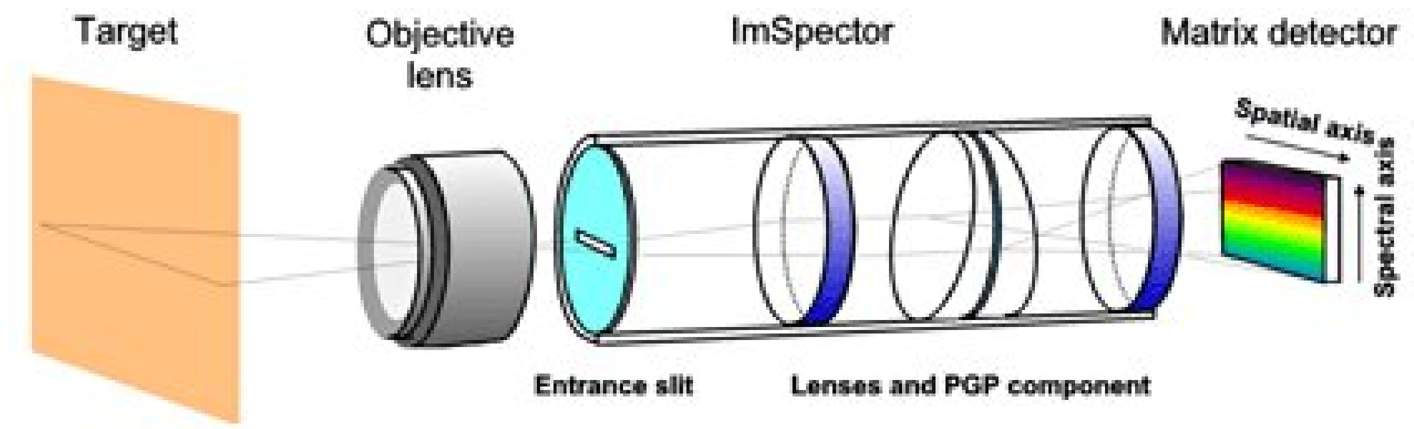
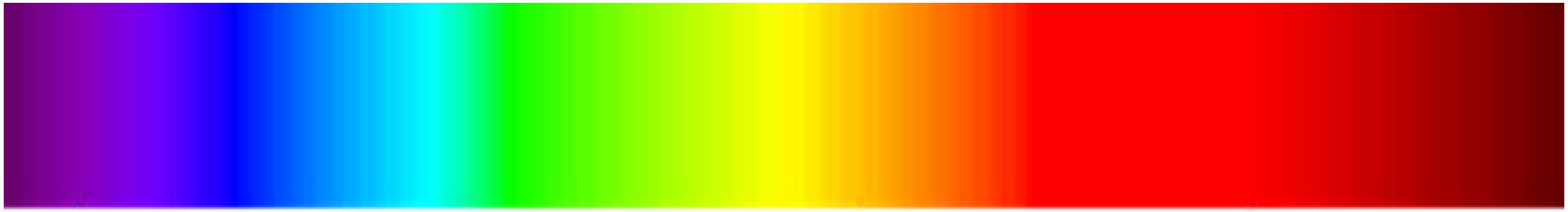
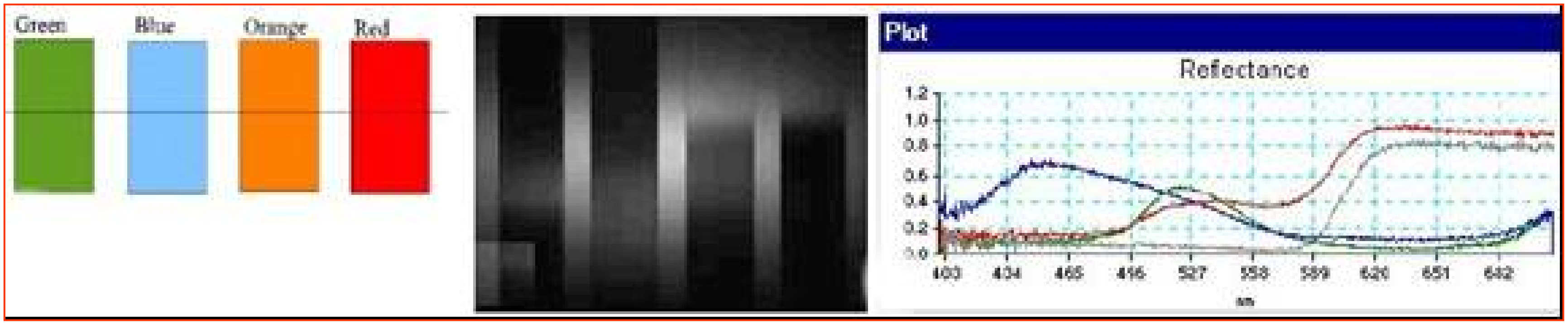
The ImSpector spectrograph



ImSpector **captures a line image of a target and disperses light from each line image pixel to spectrum. Each spectral image contains then line pixels in spatial axis and spectral pixels in spectral axis.**

Example





Scan-line across a target with green, blue, orange and red areas in white background, corresponding spectral line image and reflectance spectrum of the four different colours.

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Laboratory equipment

The moving table

Desktop Spectral Scanner

If the sample is placed on a moving table, the system scans spectral line images sequentially over the sample. The result of measurement will be a three dimensional hypercube.

Spectra have been acquired using a desktop spectral scanner by DV srl, allowing the synchronized translation of the sample.

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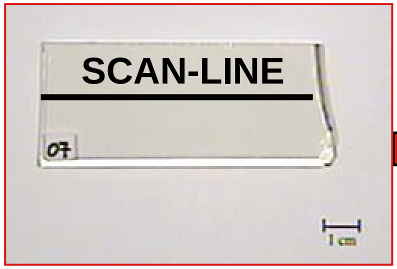
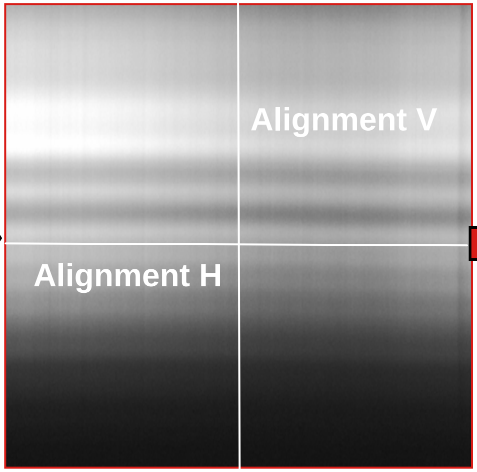
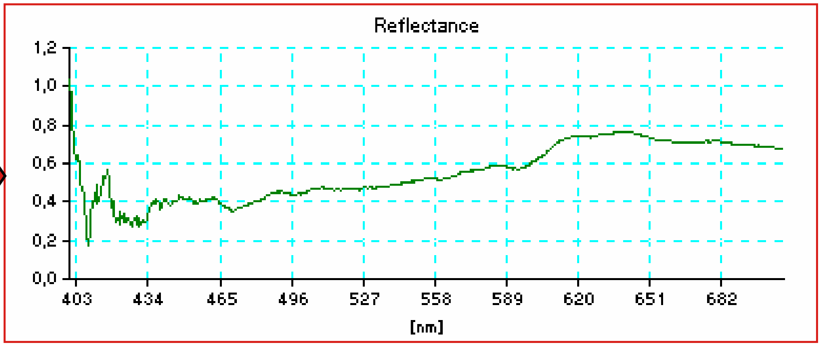
Spectra acquisition



Glass sample



Spectral image



Reflectance spectrum

The acquired spectra are analyzed as reflectance profiles, using a dark and a white standard image. The spectral intensity image of the sample is converted to a reflectance image applying pixel by pixel the following formula:

$$\text{Reflectance} = \frac{Sample - Dark}{White\ \text{-}Dark}$$

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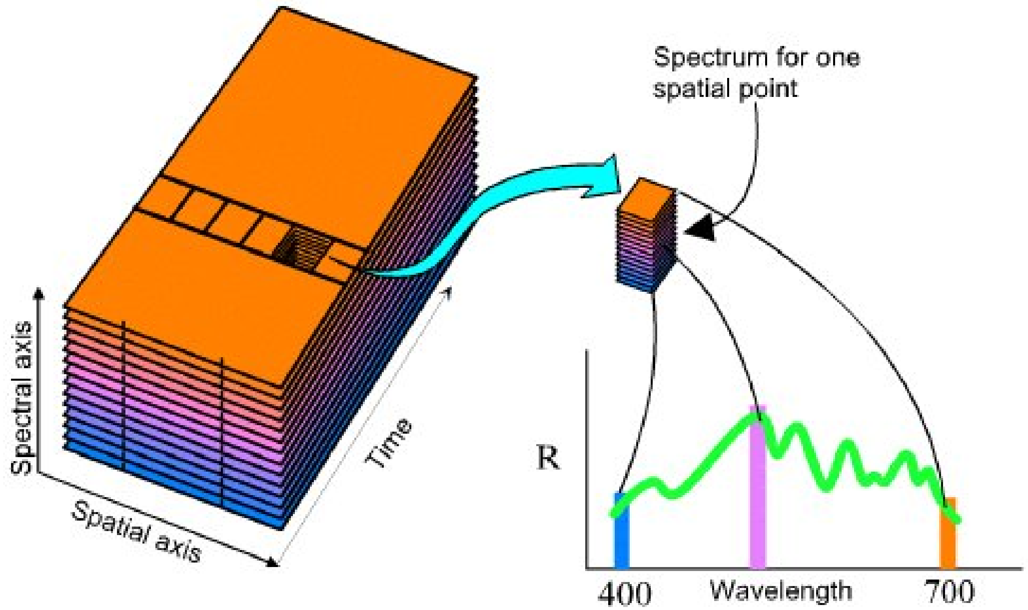
Spectra acquisition



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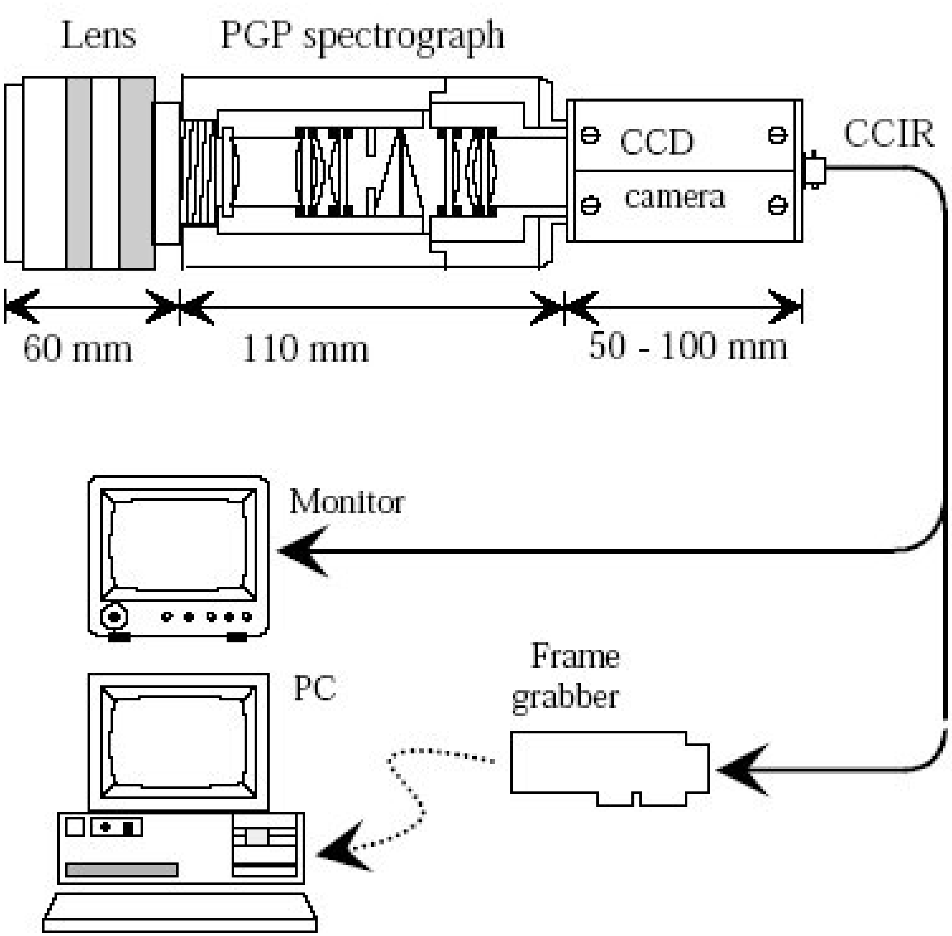
Spectral tests set-up



Solid Waste Recycling

Hyperspectral imaging based sorting strategies

Glass

Fluff

Bottom ash

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