

IDENTIFICATION OF PICTORIAL MATERIALS BY MEANS OF OPTIMIZED MULTISPECTRAL REFLECTANCE IMAGE PROCESSING

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Outline

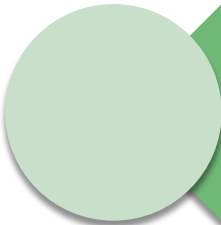


Art Forgeries



Multispectral Imaging

- Wavebands selection
- Pictorial materials recognition



Experimental evaluation

- Settings
- Results



Question & Answers

ART FORENSICS



- Different pictorial materials can have the same appearance (i.e. visual perception), but different chemical composition

ART FORENSICS



EL PAÍS

PACO DE LUCÍA Guitarrista
"Me encantaría poder vivir sin"

Arte Al via le iniziative per il quarto centenario: oggi a Firenze una rivelazione sul «Bacco» degli Uffizi

Caravaggio, autoritratto nella brocca

Mina Gregori: «Dipinse se stesso. Meglio una scoperta che mostre inutili»

di PIERLUIGI PANZA

Il ritorno al 1619: Caravaggio si dipinse in maniera microscopica dentro la brocca del suo Bacco, quasi presagio al naufragio nel vino e nei bagordi che di lì a poco avrebbe caratterizzato la sua stessa vita.

Le indagini che si sono susseguite per il IV centenario della morte del Merisi (19 luglio 1610) incominciano con questa scoperta consequenziale, come ormai sta diventando abitudine negli studi d'arte, attraverso analisi scientifiche. Una riflettografia multispettrale condotta da Art-Tesi sulla piccola agia (99 x 86 cm) del Bacco conservato agli Uffizi ha rivelato ciò che da secoli il suo spettatore, ovvero che anche il Merisi si fosse ritratto specularmente diversamente nel quadro mentre dipingeva. La novità, documentata in Nuova Scoperte sul Caravaggio, edita dalla Fondazione Roberto Longhi, sarà presentata oggi dal Comitato nazionale per le celebrazioni del IV Centenario alle 22,30 presso l'Isola Magica del Studio Art Center International (via Sant'Antonio 24, Firenze) da Mina Gregori e Roberta Lapucci.

«Oltre a caravaggesco», dice Gregori, «afferma la Gregori, una delle maggiori studiosi del pittore». Caravaggio dipinse la sagona di un personaggio in posizione eretta, con un braccio appoggiato in avanti verso un cavalletto da pittore con sopra una tela. In questa agonia sono distinguibili i lineamenti del volto, in particolare naso e occhi. Per me il suo autoritratto mentre stava dipingendo. Anche il Merisi, infatti, dipingeva utilizzando gli specchi nei quali si rifletteva, come racconta Baglione, un suo biografo: «Serviv'infatti Caravaggio...».



«Ma ancora molto delle sue attribuzioni? Precediamo il «Narciso», perché lo stesso ho sostenuto che fosse autentico, oggi siamo propensi a ritenere di altro autore, forse dello Spadaro». Il Comitato è presieduto da Maurizio Calvesi ed è stato presieduto lui, in una riunione preliminare, ricorda la Gregori, «a suggerire di finanziare un laboratorio, lo era accerta, ma nel suo non convintosi». Di certo gli studi di storia dell'arte si stanno spostando sempre più da un piano di lettura anche narrativa dell'opera (come era proprio quello del Longhi) a uno di indagini scientifiche, che di certo aumenta i dati di conoscenza, ma che non accompagnano a una vicinanza emotiva ed empatica con l'opera.

Che il volto del Merisi fosse nascosto da qualche parte nel dipinto di Bacco si sospettava. Ma nessuno l'aveva documentato. A scoglio della pittura di questa tela, nel 1924, Matteo Maroni disse infatti di aver scorto, riflessa nella brocca una testa, ma simile al «Ritratto» o al «Bacco Borghese», che volle ritogliere alla filonominia dello stesso Caravaggio: «Grandi orbite oculari ma si ha un'aria un po' commata, labbra carnee e seni sperti». Da allora solo oggi, ma agli infragorati, si riesce ad intravedere un caso di capelli neri, un accenno di volto, un tocco di bianco per il collo. Altre interpretazioni, pure autorevoli, ritengono che sia invece il volto del Bacco. Autoritratto del pittore, anche se l'ipotesi non è

Los expertos certifican un nuevo cuadro de Rafael

MIGUEL MORA, ROMA

Un nuevo cuadro de Rafael era el original. Y lo que todos pensaban que era el original era en realidad la copia. Un estudio realizado en los laboratorios de Historia del Arte de las universidades de Madrid y de la ciudad de Madrid, considerando la obra decidieron que se trataba de un original.

La obra pasó con su marca registrada en un despacho de la galería Titense de Mónaco durante meses antes de ser llevada a la intención de la restauración de la ciudad. María Jesús, que agrada los cuadros que se encuentran en esta obra para que sea

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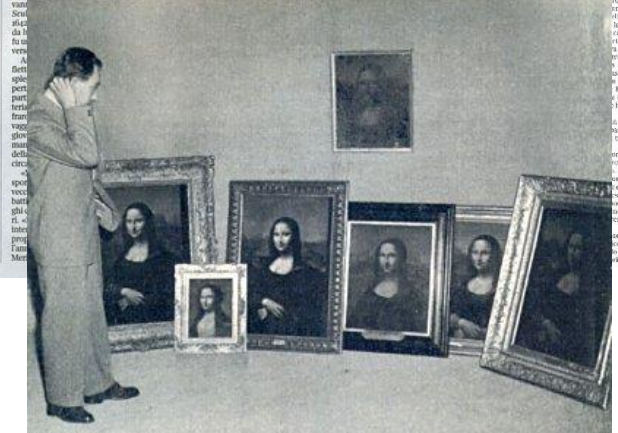
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- Identifying the materials used is often crucial to date and authenticate artworks
- Several pigments are of relatively recent discovery and production, and they could be employed only after a certain date.
- Others are no longer produced, or with different production methods.
- Diversities exist also in the geographical distribution



Yellow pigments: frequency pattern

Lead –Tin 

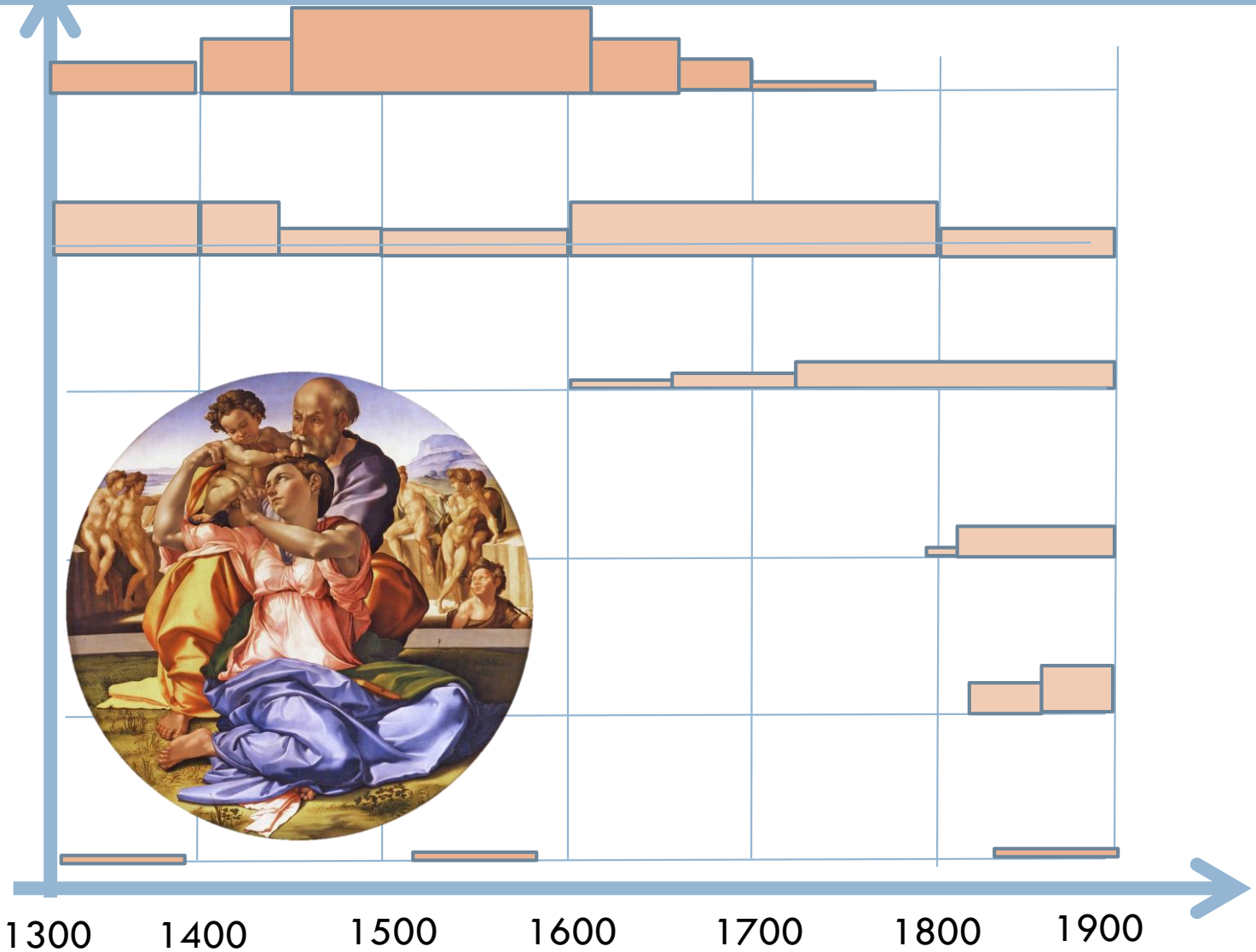
Yellow Ochre

Naples Yellow

Chromium Yellow

Cadmium Yellow 

Orpiment

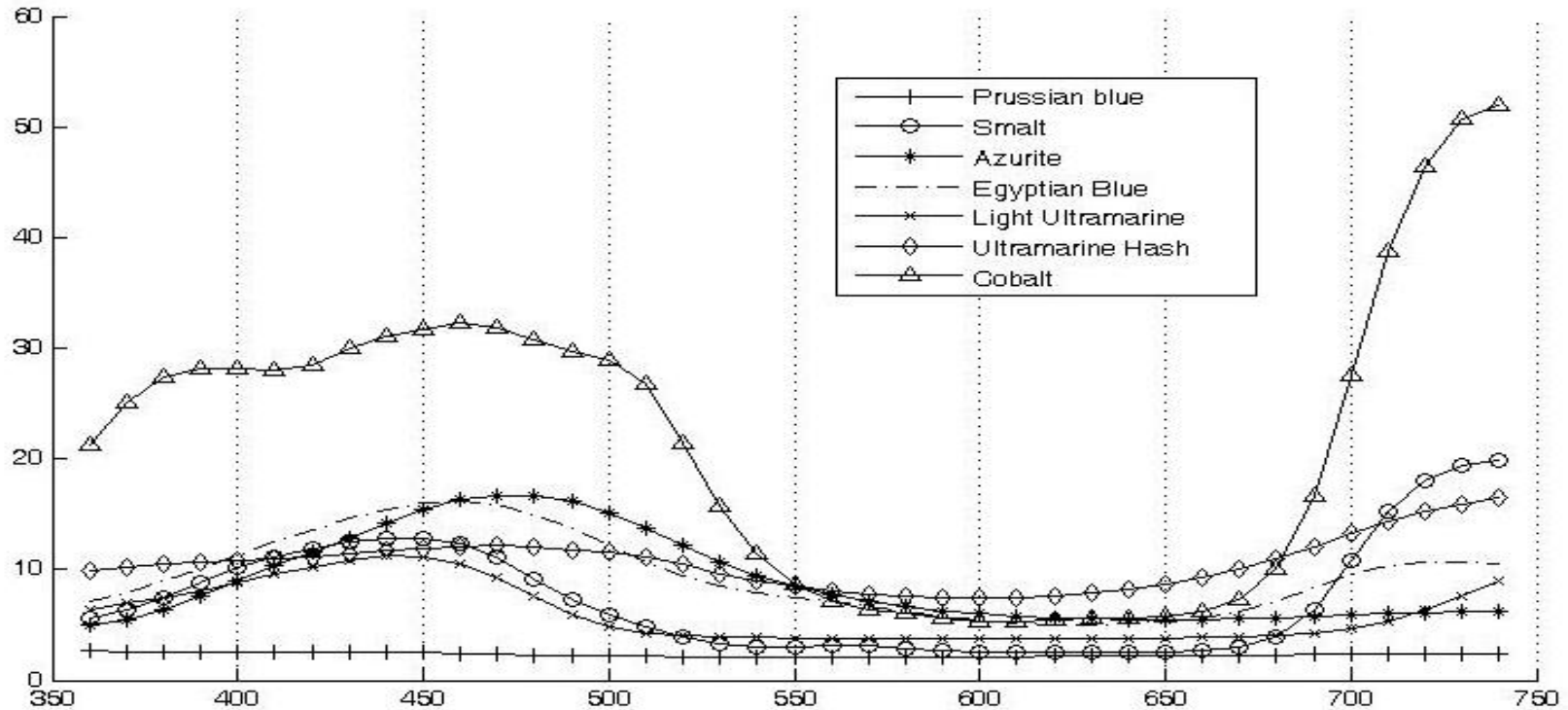


Material identification

Methods to identify materials on a painting's surface:

- Chemical analysis of microsamples of paint layer.
 - ▣ the most popular and trustworthy
 - ▣ invasive method
 - ▣ valid only for that specific specimen
- Image spectroscopy
 - ▣ exploits the fact that materials reflect electromagnetic radiation in ways that depend on their molecular composition and shape
 - ▣ non-invasive method
 - ▣ on the entire painting's surface at once

Reflectance Spectra

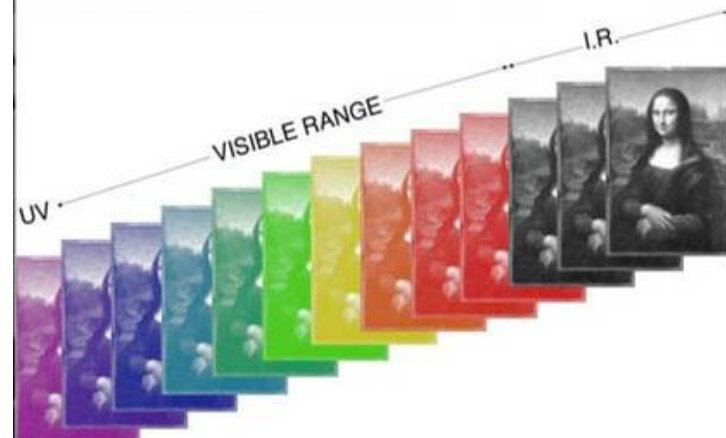
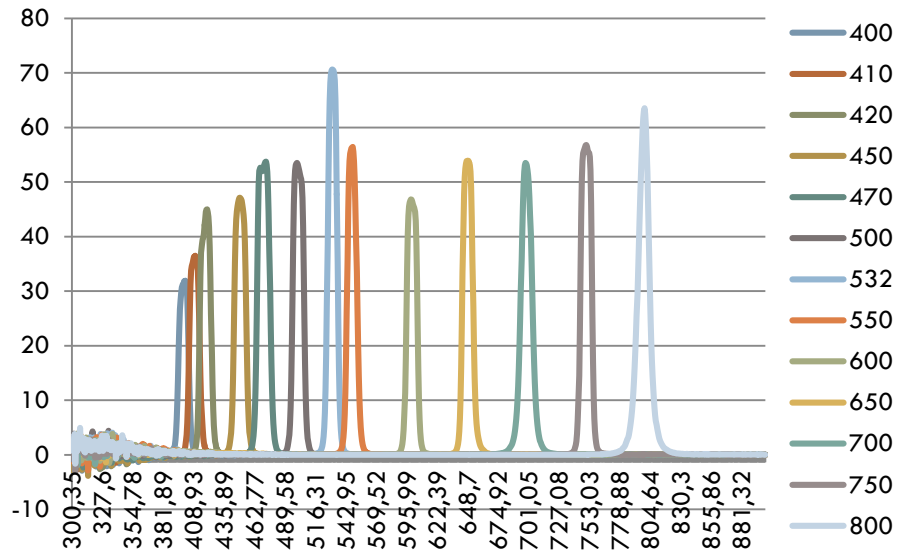


Example of spectra of blues acquired by using the Minolta spectrophotometer for a given support

A decorative horizontal bar at the top of the slide, consisting of an orange rectangular block on the left and a blue rectangular block on the right.

Multispectral Imaging of Paintings

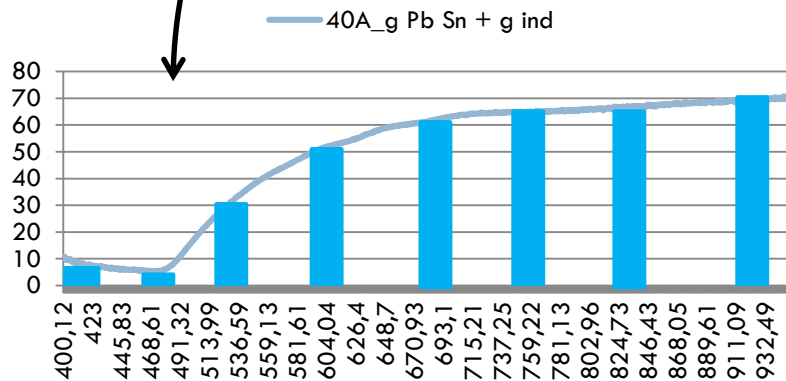
Multispectral Reflectance Imaging



- A camera equipped with interdigital filters allows to acquire reflectance of paintings at different wavelengths

Identification of pictorial materials

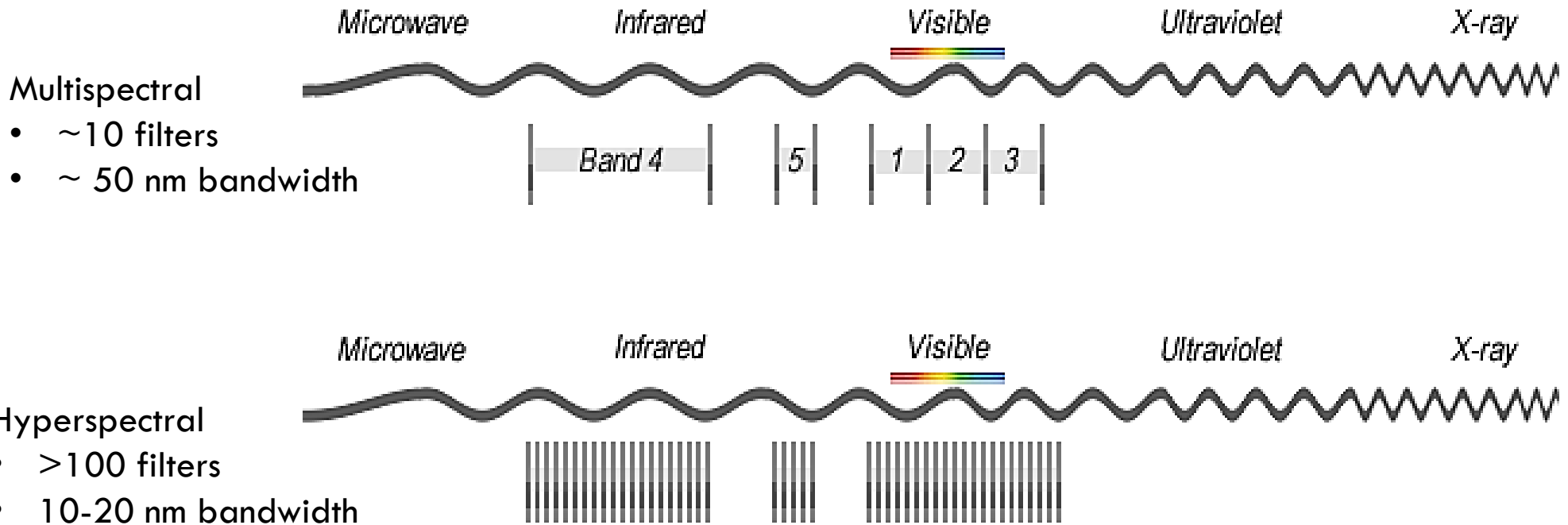
- A pictorial material can be classified/recognized by using its reflectance spectra



Reference spectrum

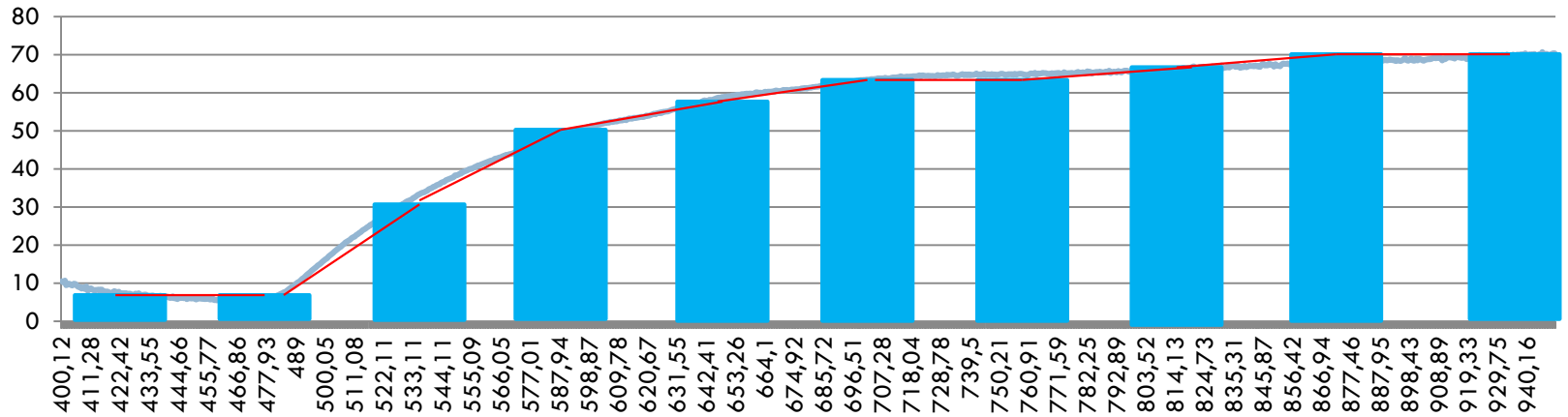
Multispectral vs Hyperspectral

- Current trend is to pass from Multispectral to Hyperspectral Imaging

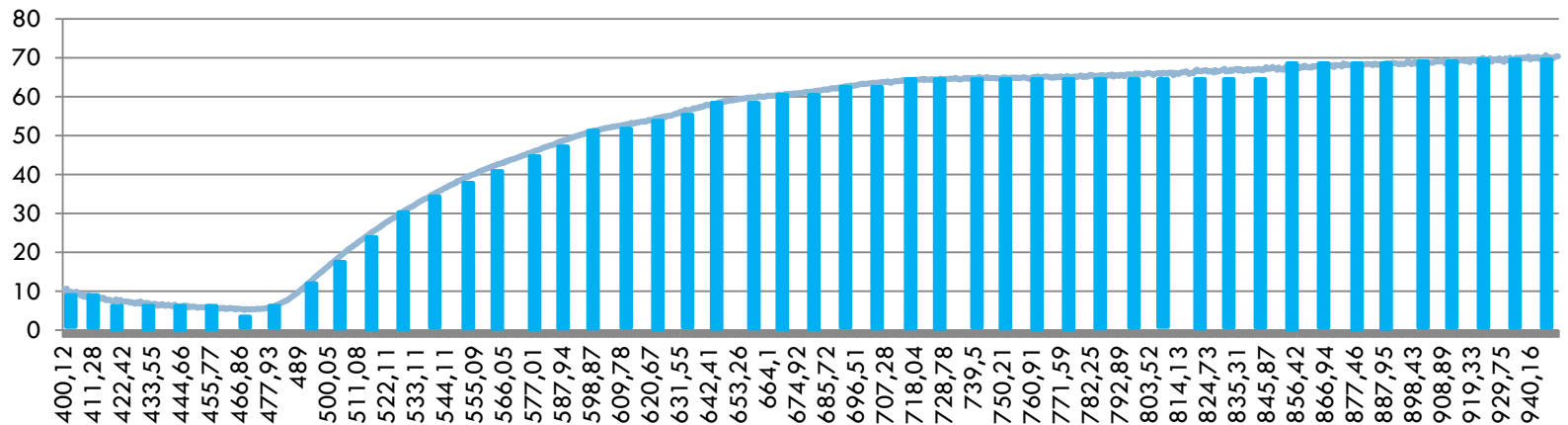


Multispectral vs Hyperspectral

Multispectral



Hyperspectral



accuracy achieved in reconstructing the actual spectra is much higher !!

Data Reduction

- Hyperspectral techniques increase

- ▣ Complexity (HW and SW)

- ▣ Costs

- ▣ Time

but accuracy?

- To discriminate pictorial metameric pigments, is it necessary acquire a lot of wavebands?

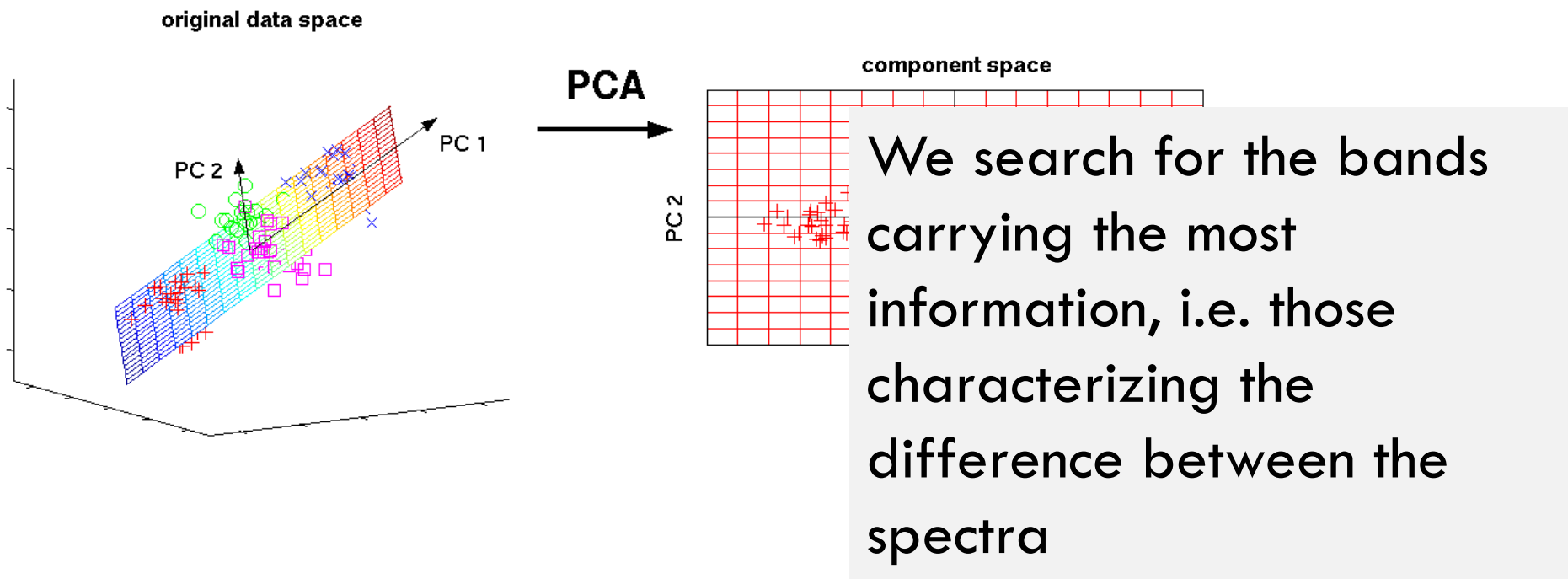
- ▣ what bands are actually necessary and what is the desired spectral resolution ?

Aim of this work

- Optimizing, and thus reducing, the number of filters employed, while still providing a robust method
- To achieve similar performances as traditional ones, which in turn employ a large number of filters.

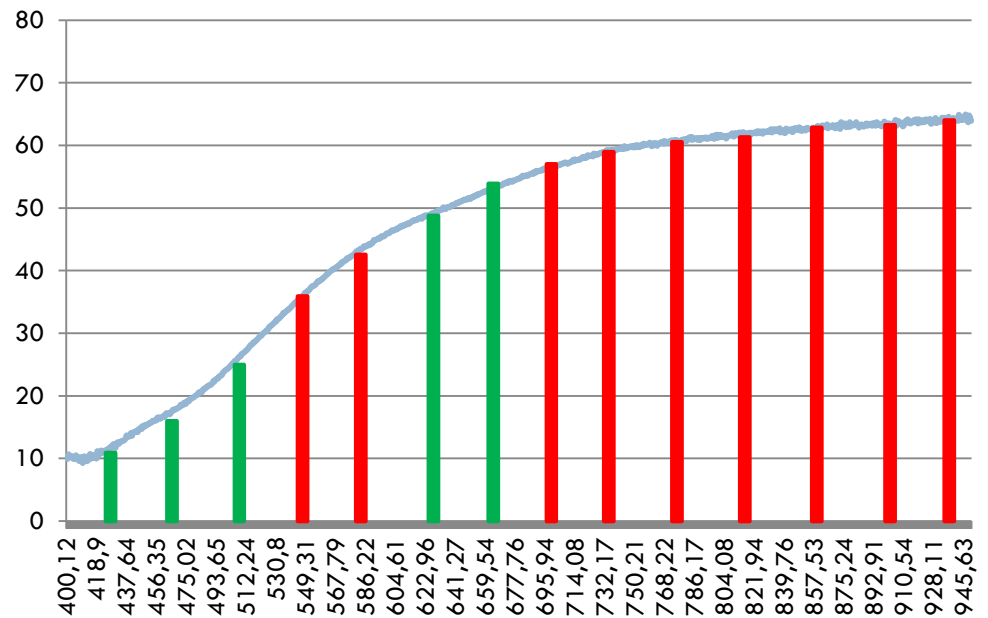
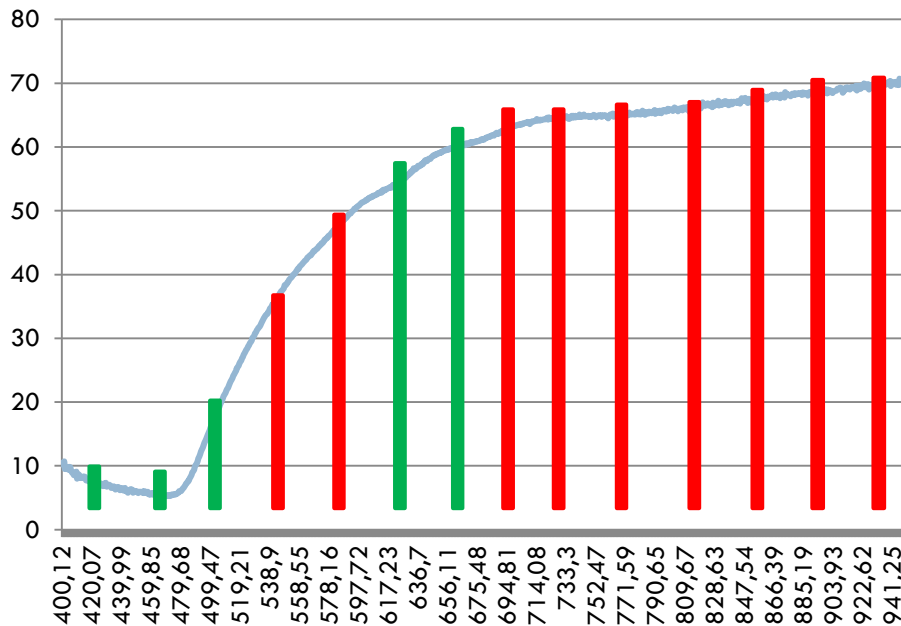
PCA based approach

- Well known technique employed in data analysis, reduction and compression



PCA based approach

- 2 spectra, which are basically the same color: Yellow.
- By using PCA, we want to select a limited number of sub-bands: those contain the most of discriminative information



Idea



- We define a **criteria to select a subset of wavebands** that allows to discriminate pictorial materials
- We order wavelengths in function of the **score distance**

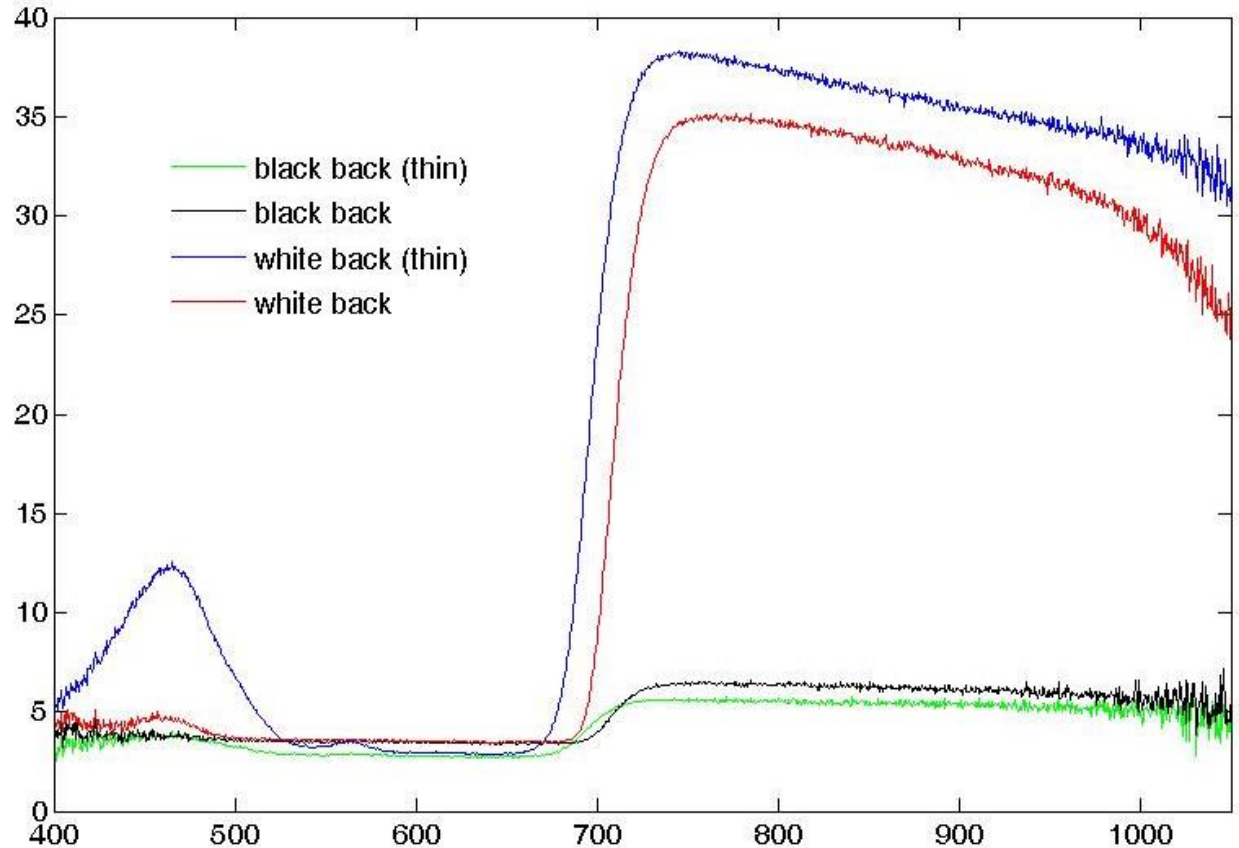
$$SD_i = \left[\sum_{k=1}^p \frac{t_{ik}^2}{v_k} \right]^{1/2}$$

- t_{ik} are the elements of scores matrix, v_k is the variance
- The 4 outliers are selected

Issues

Measured reflectance influenced by :

- Thickness of material
- Kind of support
- aging
- Smalt in oil



Wavebands selection criteria

1. Reflectance spectra

- ▣ It depends on reflectance **values**

2. Derivative of spectra

- ▣ It depends on the reflectance **spectral features** (as peaks and slopes): less dependent from age

- ▣ **Bands < 650 nm.**

- ▣ Above this value, reflectance spectra are affected by the under-laying materials

Similarity measure

- **Spectral Angle Mapper** has been used to classify pixels belonging to a given pictorial material

$$\theta = \frac{\langle \bar{s}, \bar{r} \rangle}{\sqrt{\|\bar{s}\| \|\bar{r}\|}}$$

- $\bar{s} = [s_1, s_2, \dots, s_N]$ and $\bar{r} = [r_1, r_2, \dots, r_N]$ are the measured and reference spectra, sampled by interferential filters



Experimental settings

Technologies

□ **Multispectral imaging system**

- A monochromatic QSI 583w camera with a CCD full-frame sensor (KAF8300) with 3326x2504 pixels (pixel size of 17.96mm x 13.52mm), equipped with an internal wheel with interferential filters
- Two lamps at 45 degrees angle to the surface
- Filters: FWHM of 10 nm with central wavelengths of 400, 410, 420, 450, 470, 500, 532, 550, 600, 650, 700, 750 and 800 nm

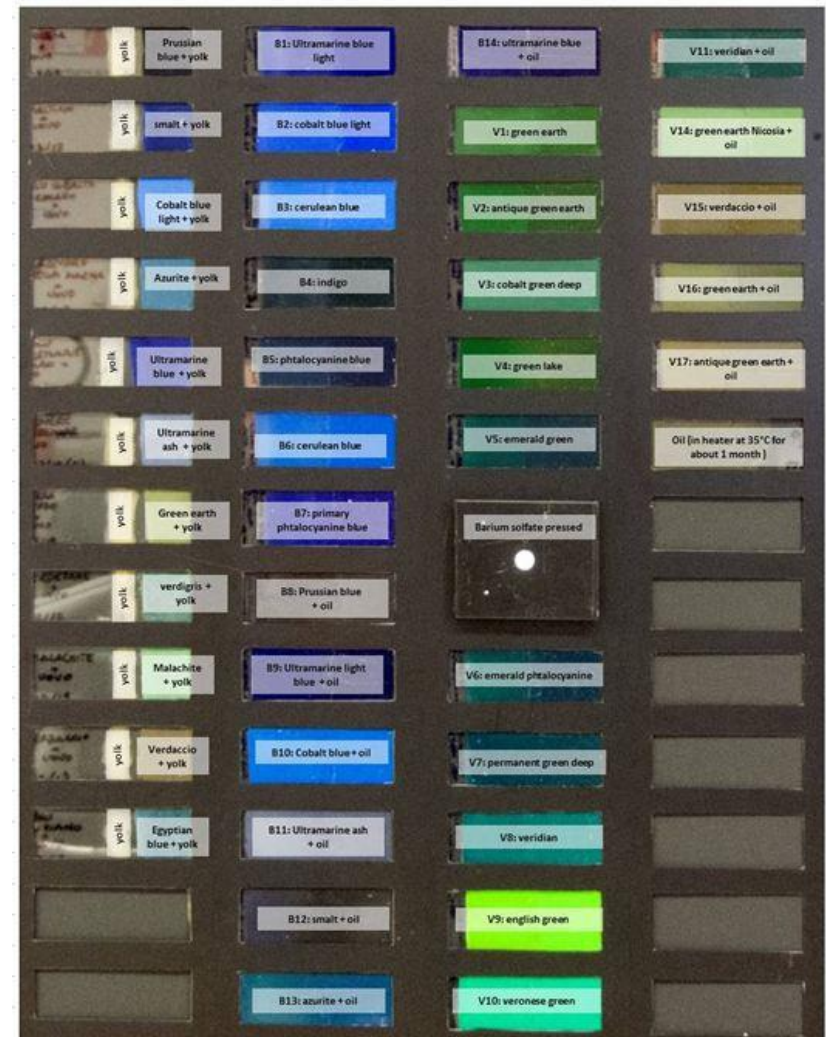
□ **Spectrometer equipped with a halogen lamp**

- (AvaSpec-2048-USB2, Avantes) connected to a halogen lamp (HL-2000-FHSA, Avantes) with optical fibers.
- With a diffraction grating of 300 lines/mm for a blaze-wavelength efficiency of 500 nm and a 2048 pixels array CCD sensor.
- The spectral resolution is 0.8 nm.
- The geometry of illumination is 45/0°

□ **Spectrophotometer**

- CM-2300d, a Minolta portable integrating sphere spectrophotometer, that uses a d/8° geometry
- two pulsed xenon lamps as light source
- wavelength range from 360 to 740nm
- the wavelength pitch is 10 nm with a half bandwidth of 10nm

Pictorial Materials





Results

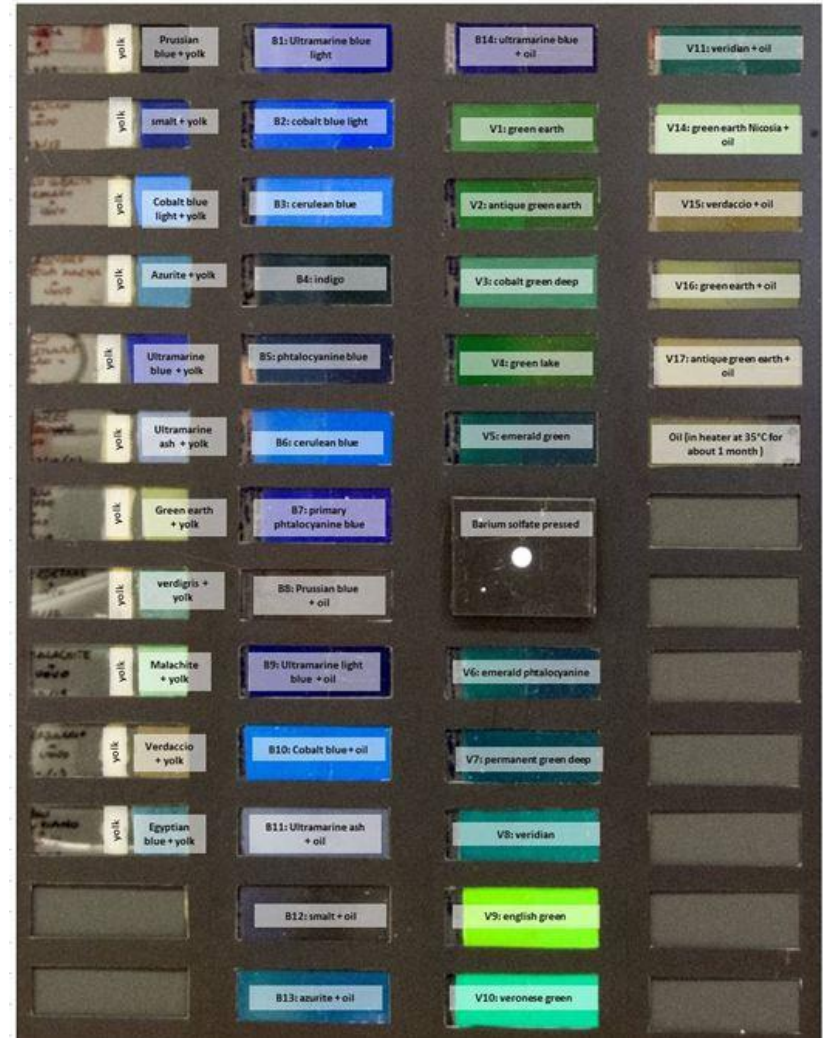
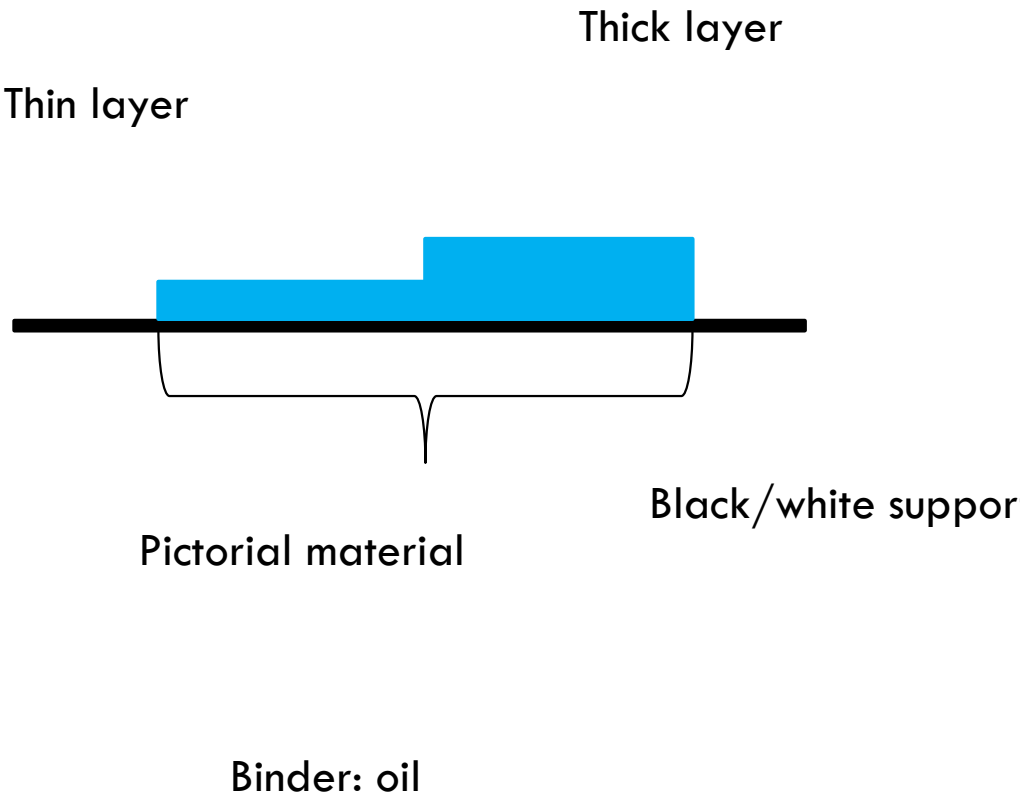


Training

- We assume to a *priori* separate pictorial materials in color classes (blues, greens, yellows, reds, whites...)
- For each class of colors, PCA is applied to select 4 most informative wavelength among the 13 available filters for multispectral imaging .
- Training set: egg yolk as binder

Blue		Greens		Orange/Red/Brown		Yellow	
R	$\frac{\partial R}{\partial \lambda}$	R	$\frac{\partial R}{\partial \lambda}$	R	$\frac{\partial R}{\partial \lambda}$	R	$\frac{\partial R}{\partial \lambda}$
470	700	500	500	600	600	500	500
450	500	530	550	700	550	530	550
600	410	400	530	650	470	400	400
650	400	410	400	400	450	410	600

Test Materials



Performance

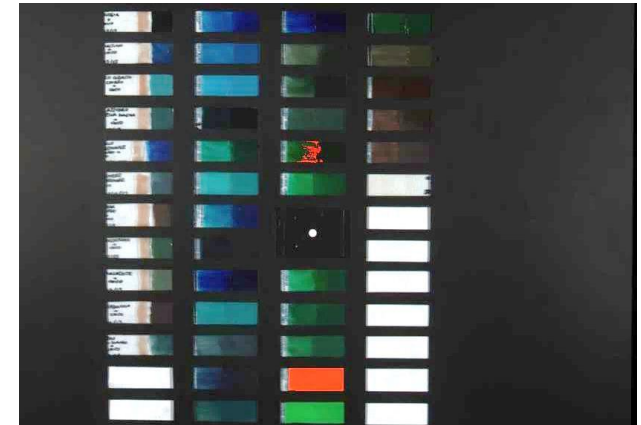
- Performance are evaluated in terms **ROC**
- Area Under the Curve are reported

	AUC values	
	Selected wavebands	Average
All image background	all available	0.9050
All image background	PCA Spectra	0.7975
All image background	PCA Deriv.	0.8725
All image background	3Filter<650nm	0.7933

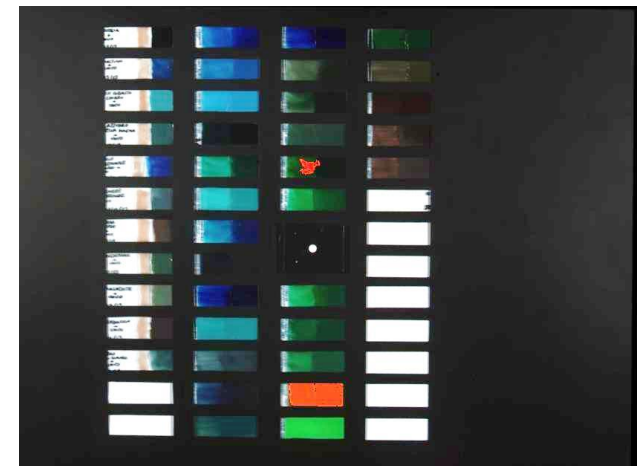
Example

English Green

	Reference Spectra support				
Image Support	Selected wavebands	white thin	white	black thin	black
White	all available	0.99948	0.99914	0.99935	0.99915
Black	all available	1	1	1	1
White	PCA Spectra	0.99768	0.99769	0.99746	0.99769
Black	PCA Spectra	1	1	1	1
White	PCA Deriv.	0.96747	0.99585	0.96422	0.9936
Black	PCA Deriv.	1	1	1	1
White	3Filter <650nm	0.99734	0.9975	0.99408	0.9975
Black	3Filter <650nm	1	1	1	1



All filters used



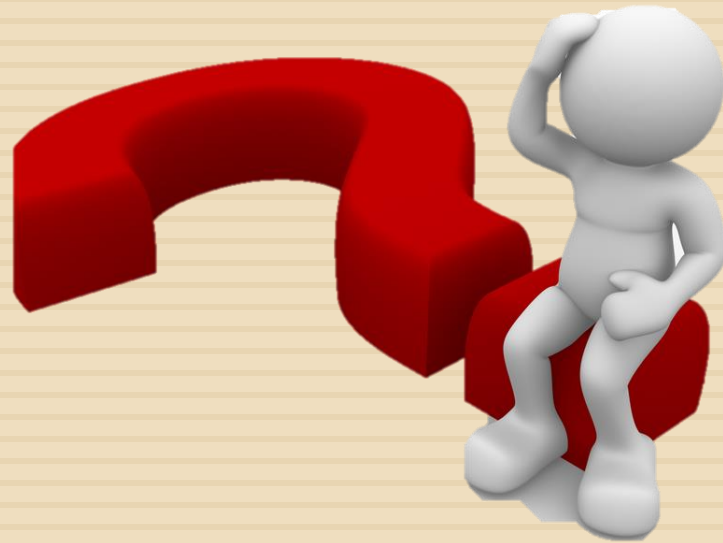
4 filters PCA Derivative

Conclusions

- A multispectral imaging system equipped with narrow band filters has been used to identify pictorial materials
- The work shows how using PCA we were able to select the most informative wavebands, without a substantial performance reduction
- Future plans: To extend the method to fluorescence multispectral imaging



Thank you!



Questions?

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