“Non-destructive identification of the “DNA” of art objects using remote sensing and tomographic techniques”

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“Ormylia” Foundation
www.ormyliafoundation.gr

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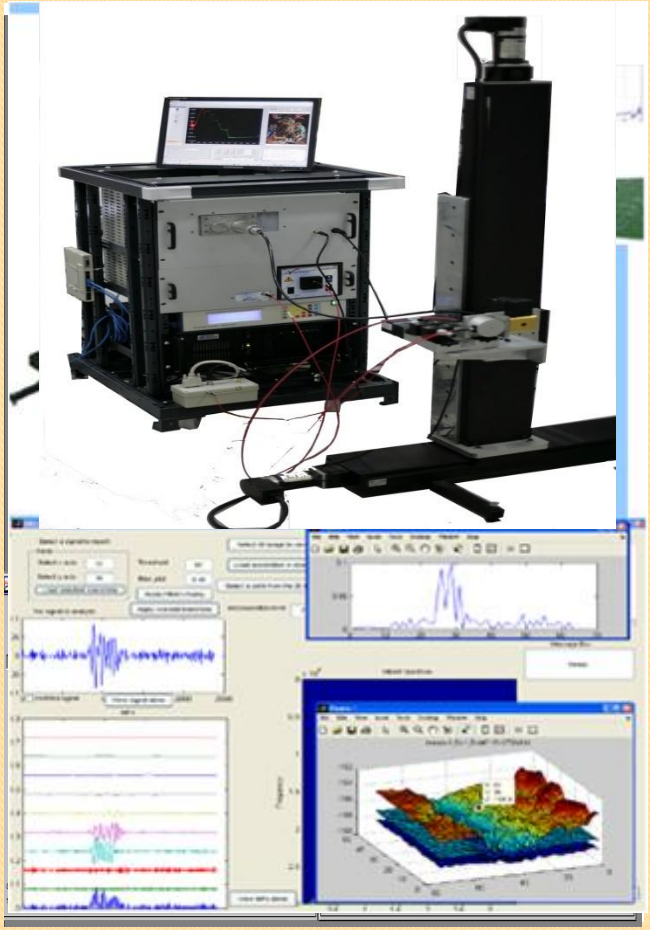
Current stage of technological applications and studies



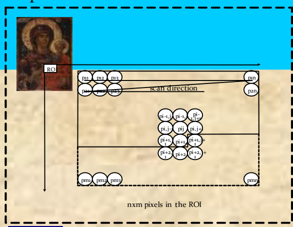
Multispectral Imaging
- Visible
- UV Fluorescence
- IR Reflectograms
- X-Radiographs
- Colorimetry

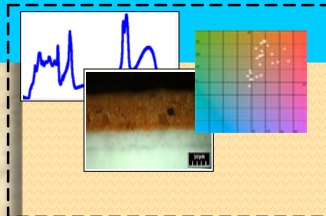
Optical Microscopy Cross-section micrographs

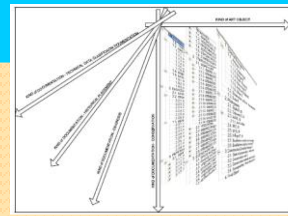
Spectroscopies
- Micro FT-IR
- Micro Raman
- Chromatographic techniques

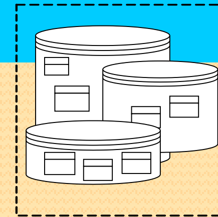
Data acquisition with novel custom made devices Developed in the Lab of OF - ADC

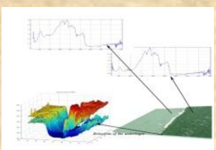
Art Diagnosis Centre

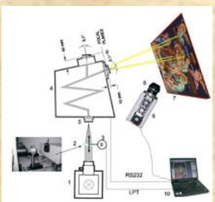


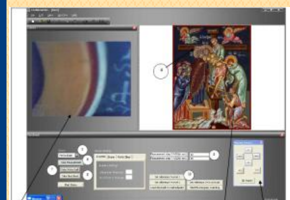


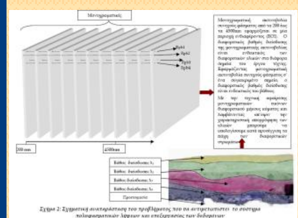






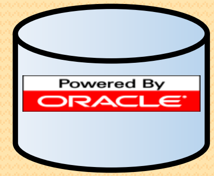


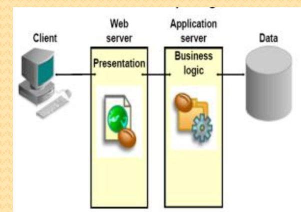


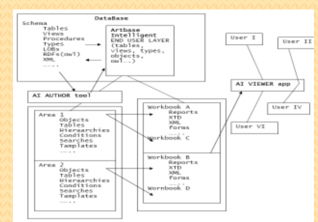


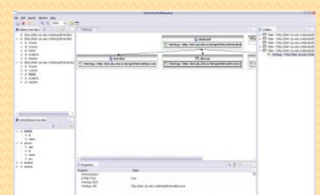
Πίνακας 1: Κατηγορίες χρηστών και προβλεπόμενες εφαρμογές

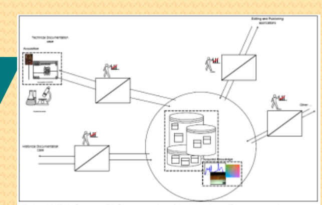
Κατηγορίες χρηστών	Γενικό ενδιαφέρον για τα έργα Τέχνης	Προβολή, δημιουργία ηλεκτρονικών εκδόσεων - Εκπαίδευση	Ιστορικοαισθητική προσέγγιση	Ανάλυση, τεκμηρίωση, Συντήρηση
Ο χρήστης "συγγραφέας"				
Εκδότης		x	x	x
Επιστήμονας συντήρησης / Συντηρητής		x		x
Ιστορικός τέχνης		x	x	
Μελετητής -διαχειριστής συλλογών		x	x	x
Ο χρήστης "επισκέπτης"				
Φιλότεχνος επισκέπτης χωρίς ειδική γνώση	x	x		
Επιστήμονας συντήρησης / Συντηρητής		x		x
Ιστορικός τέχνης		x	x	
Ζωγράφος	x	x	x	x

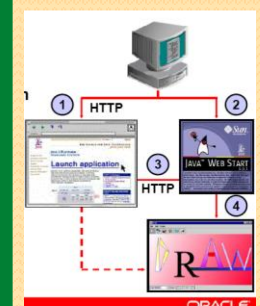


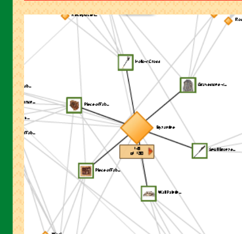




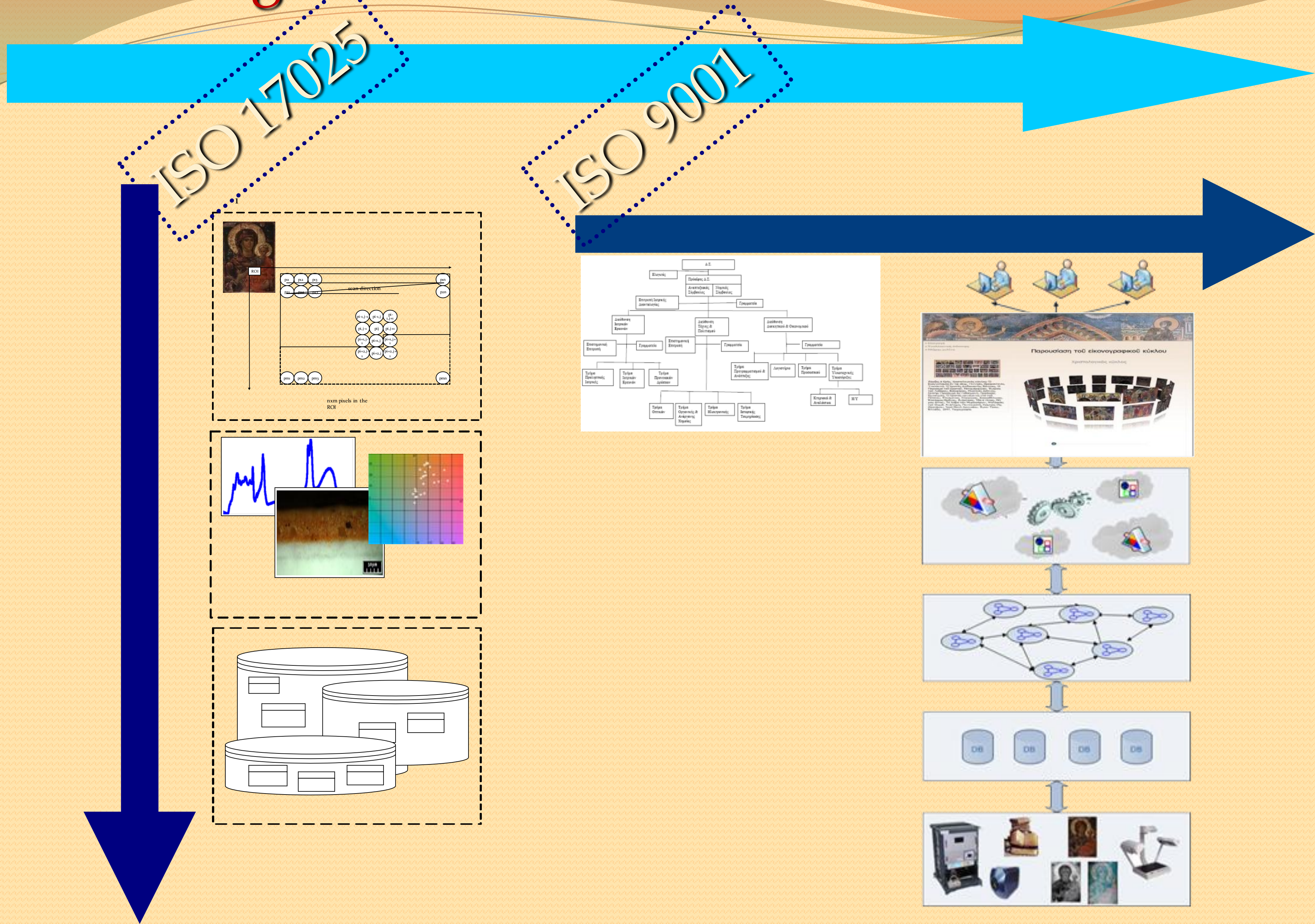








Art Diagnosis Centre



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Current stage of technological applications and studies

Cross disciplinary case studies… tracing the roots of our Cultural Heritage …

Bronze era
Greek
(17th century BC)

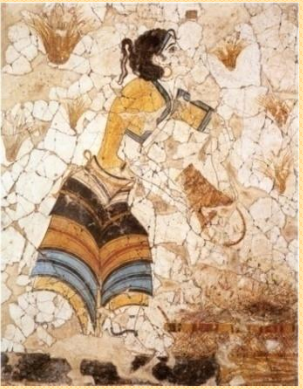
Modern
Painting
(20th century
AC)

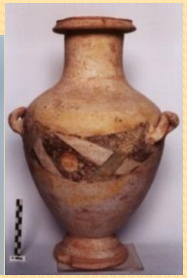
Greek
Classical
period

Roman – Greek
period

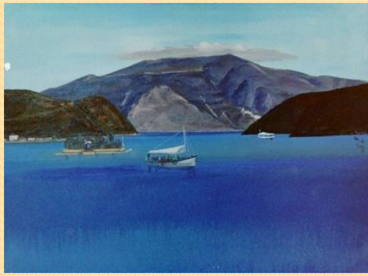
Byzantine period

Post
Byzantine









Vision

Alexander the Great said:

To my Father I ought the fact that "I live" («ζεἰν») to my teacher the fact that I live in prosperity («εὐ ζεἰν»).

Prosperity : Meaning the well being, having deep knowledge of the "Greek" Culture- being cultivated, living according to diachronic values and principles in principal.

The teacher was the Philosopher Aristoteles and the knowledge that was provided to him was part of our heritage … … …

Vision

Trace the roots and the different views of our common cultural heritage

International Cooperation for exchanging our experiences – technology transfer

Technology (Τεχνολογὶα ~ Τὲχνη (art) & λὸγος (Talk-wisdom- …))

So technology means "talking" for art …

The concept

Conservation science after many years of research experience provides us with significant tools in order to “identify” bottom up with high fidelity information the art objects. Especially, the reveal of the internal structure - stratigraphy which provides important information related to the materials and the technique used for the creation of the object.

These materials and the techniques are the components of the “DNA” of the object.

The components which were used during the creation phase of the object and being altered due to the past time as well as due to restoration – conservation attempts have as a result this object to appear to its current state of “existence”-preservation.

The identification of all this knowledge related to the **materials** and their reaction-affection-alteration caused by the environmental conditions and the light, their distribution on the surface and in depth which is the **technique** as well as **later significant interventions** to the objects affecting the current state of preservation- existence (like restoration, consolidation, overpaintings etc), **the micro and macro characteristics** of all these (materials, techniques, interventions) of the object comprise the **“DNA” of the object**.

The concept

The “DNA” is the way with which we “identify” a human being … similar to this, the art object “DNA” is way in order to identify and trace it. This information is up to now mainly acquired through analytical spectroscopic methods, which require a micro-sampling operation and time consuming work in the laboratory.

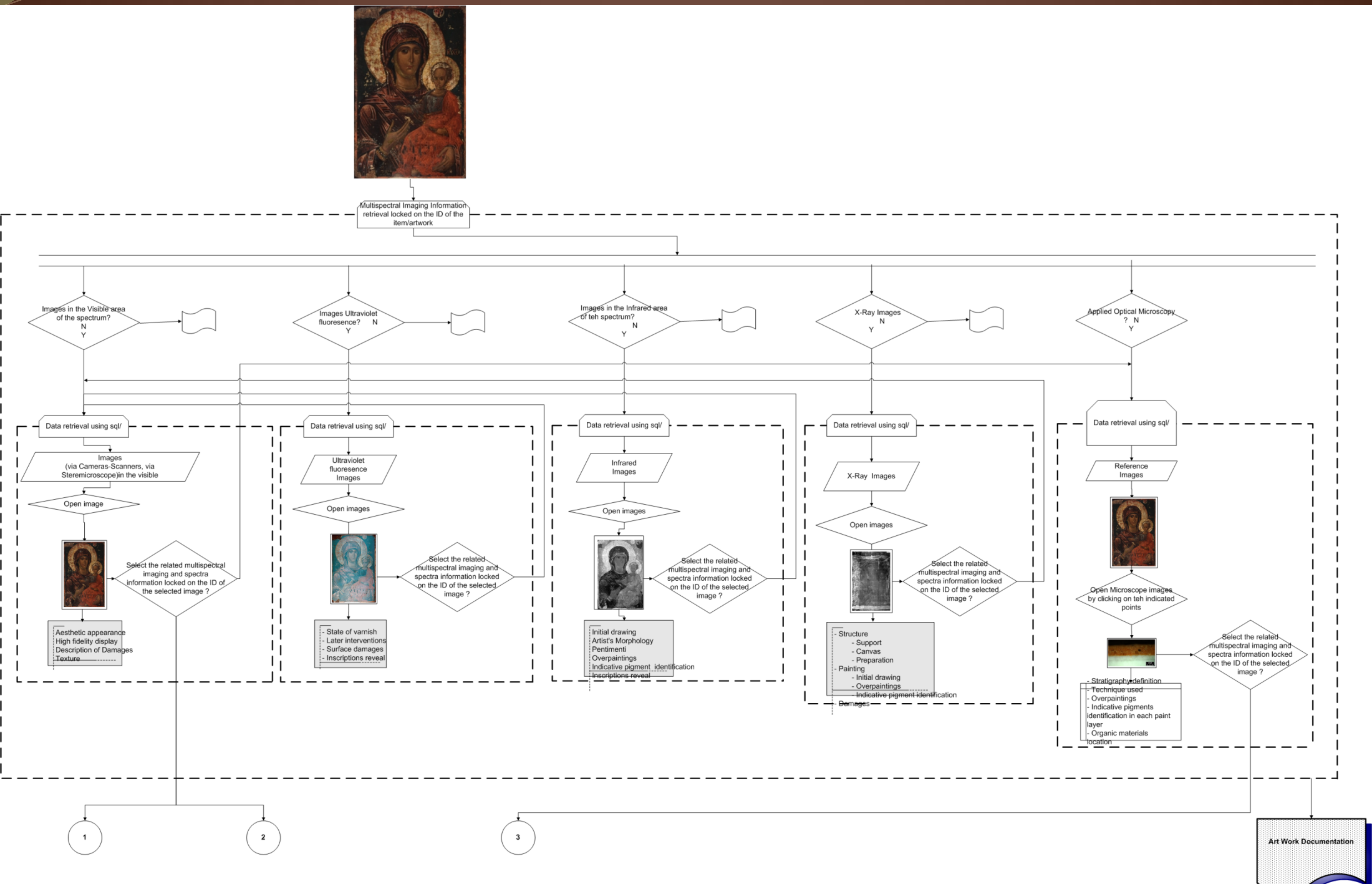
Most of the times, the objects under study are highly valuable and therefore must not be subjected to any intervention consequently, Non Destructive Testing (NDT) tomographic techniques to reveal of the information that stems from the art objects internal paint layers (stratigraphy) as well as the surface is imperative in order to store and handle it as the “DNA” of them.

The concept

The need of portable systems for fast and “easy” in situ measurements and storage of the “DNA” even from non experts is evident.

The fidelity and the resolution of the information is an issue. … Do we need high resolution and fidelity information which eventually cannot be traced in future measurements or we need “lower” resolution – fidelity still reproduced secure information which will be traceable lifelong?

The concept

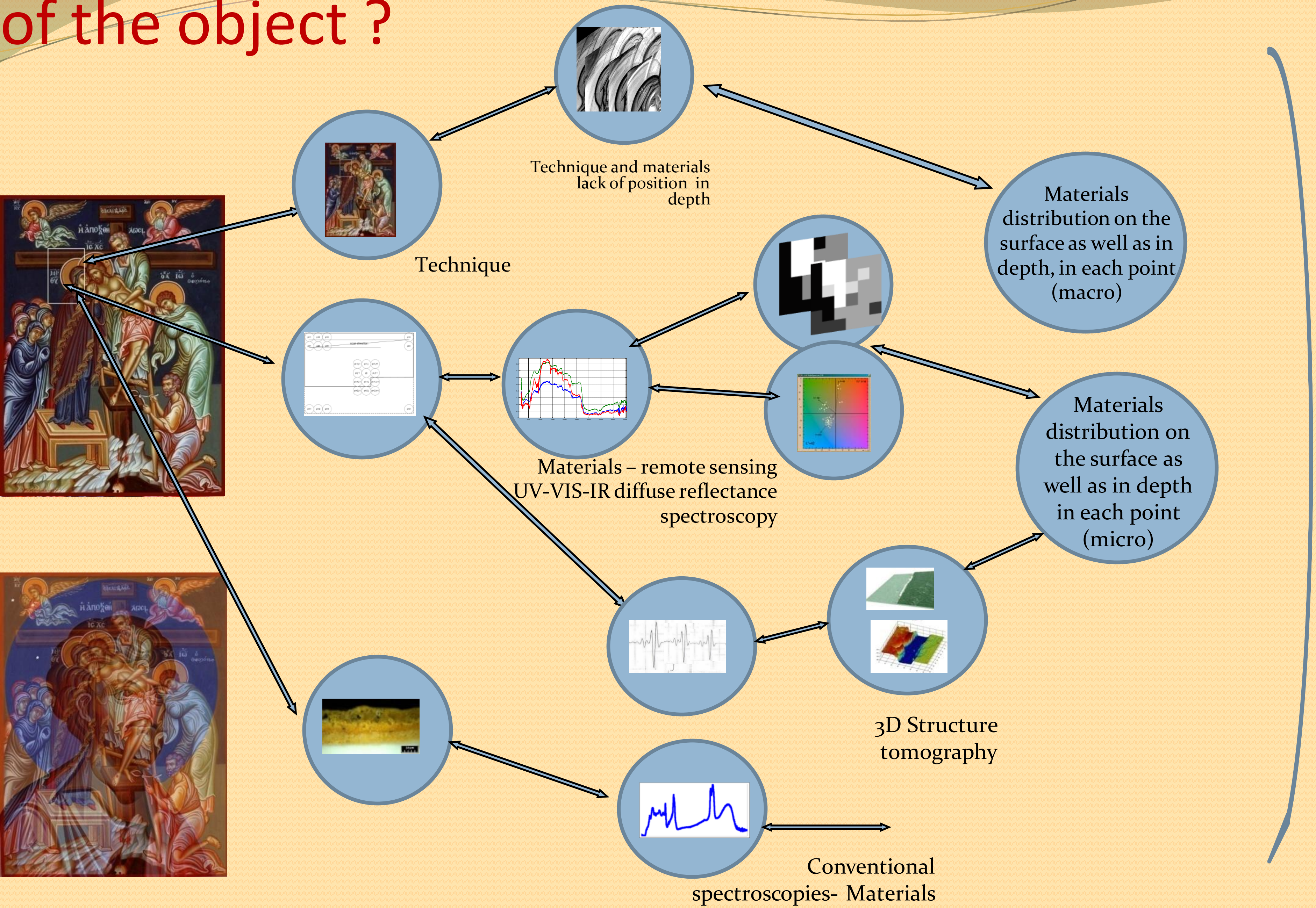


Multispectral Imaging Information retrieval locked on the ID of the item/artwork
Images in the Visible area of the spectrum? N Y
Images Ultraviolet fluoresence? N Y
Images in the Infrared area of teh spectrum? N Y
X-Ray Images N Y
Applied Optical Microscopy ? N Y
Data retrieval using sql/
Images (via Cameras-Scanners, via Steremicroscope)in the visible
Open image
Select the related multispectral imaging and spectra information locked on the ID of the selected image ?
Aesthetic appearance
High fidelity display
Description of Damages
Texture
Ultraviolet fluoresence Images
Open images
Select the related multispectral imaging and spectra information locked on the ID of the selected image ?
- State of varnish
- Later interventions
- Surface damages
- Inscriptions reveal
Infrared Images
Open images
Select the related multispectral imaging and spectra information locked on the ID of the selected image ?
Initial drawing
Artist's Morphology
Pentimenti
Overpaintings
Indicative pigment identification
Inscriptions reveal
X-Ray Images
Open images
Select the related multispectral imaging and spectra information locked on the ID of the selected image ?
- Structure
- Support
- Canvas
- Preparation
- Painting
- Initial drawing
- Overpaintings
- Indicative pigment identification
- Damages
Reference Images
Open Microscope images by clicking on teh indicated points
Select the related multispectral imaging and spectra information locked on the ID of the selected image ?
- Stratigraphy definition
- Technique used
- Overpaintings
- Indicative pigments identification in each paint layer
- Organic materials location
1
2
3
Art Work Documentation

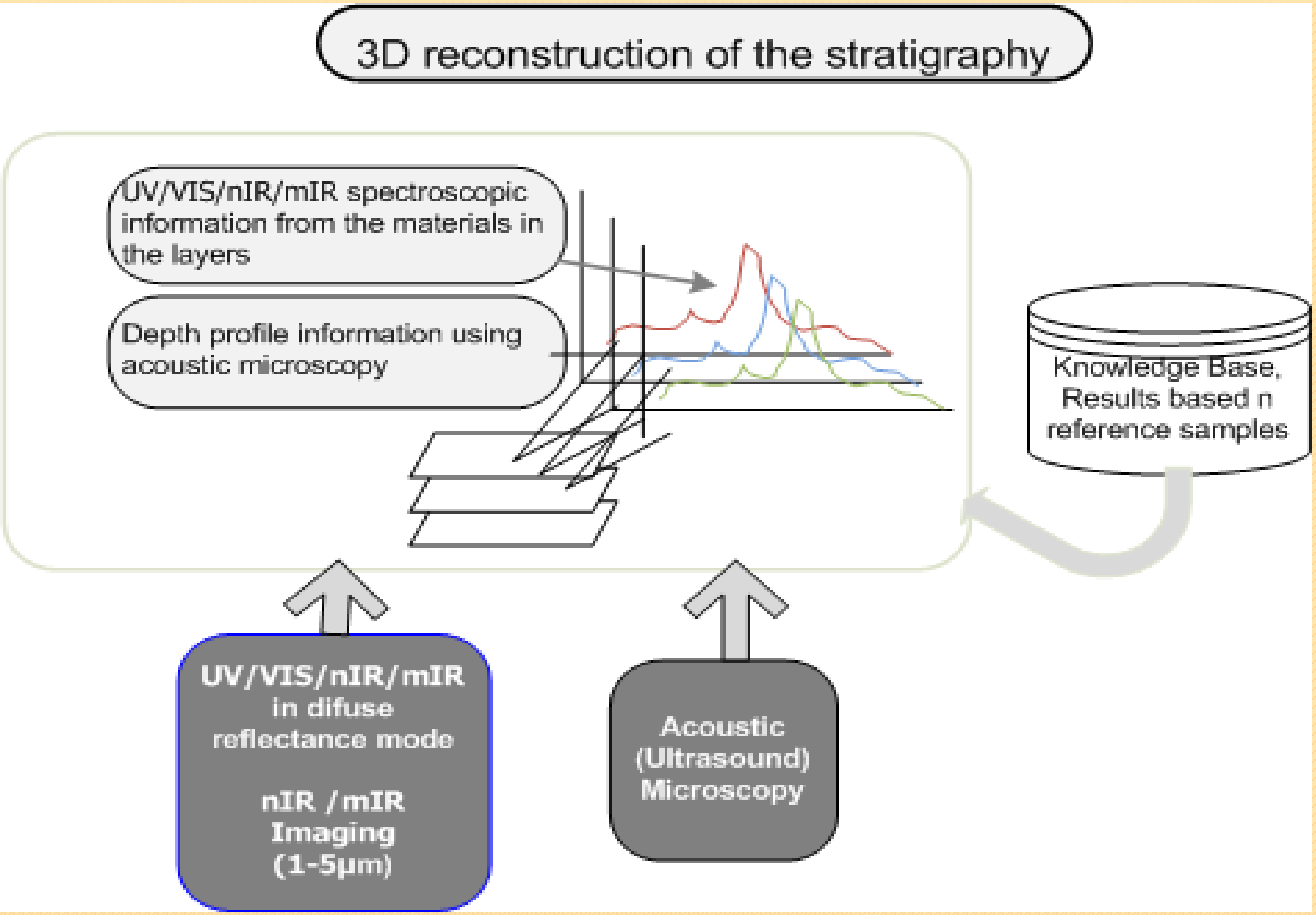
The concept

from 2
from 3
from 1
of the item/artwork
UV/VIS/nIR spectral Information?
N
Y
Different Cleaning levels?
N
Y
For each cleaning level
Open Reference Image
UV/VIS/nIR Spectra
- Indicative materials identification
- Colour measurement
μRaman spectral Information?
N
Y
Open Reference Image
Data retrieval using sql/
μRaman Spectra
- Inorganic Materials identification (pigments used in each paint layer)
- Special case (Inorganic materials identification)
μFTIR spectral Information?
N
Y
Open Reference Image
μFTIR Spectra
- Organic Materials identification
-Media
-Pigments
-Varnishes
Art Work Documentation

The concept- Could we say that this is the "DNA" of the object ?

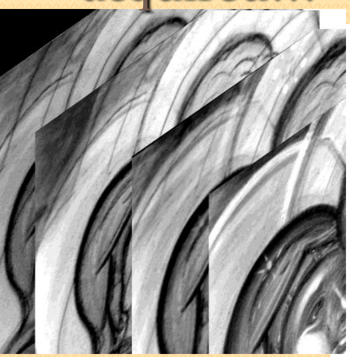


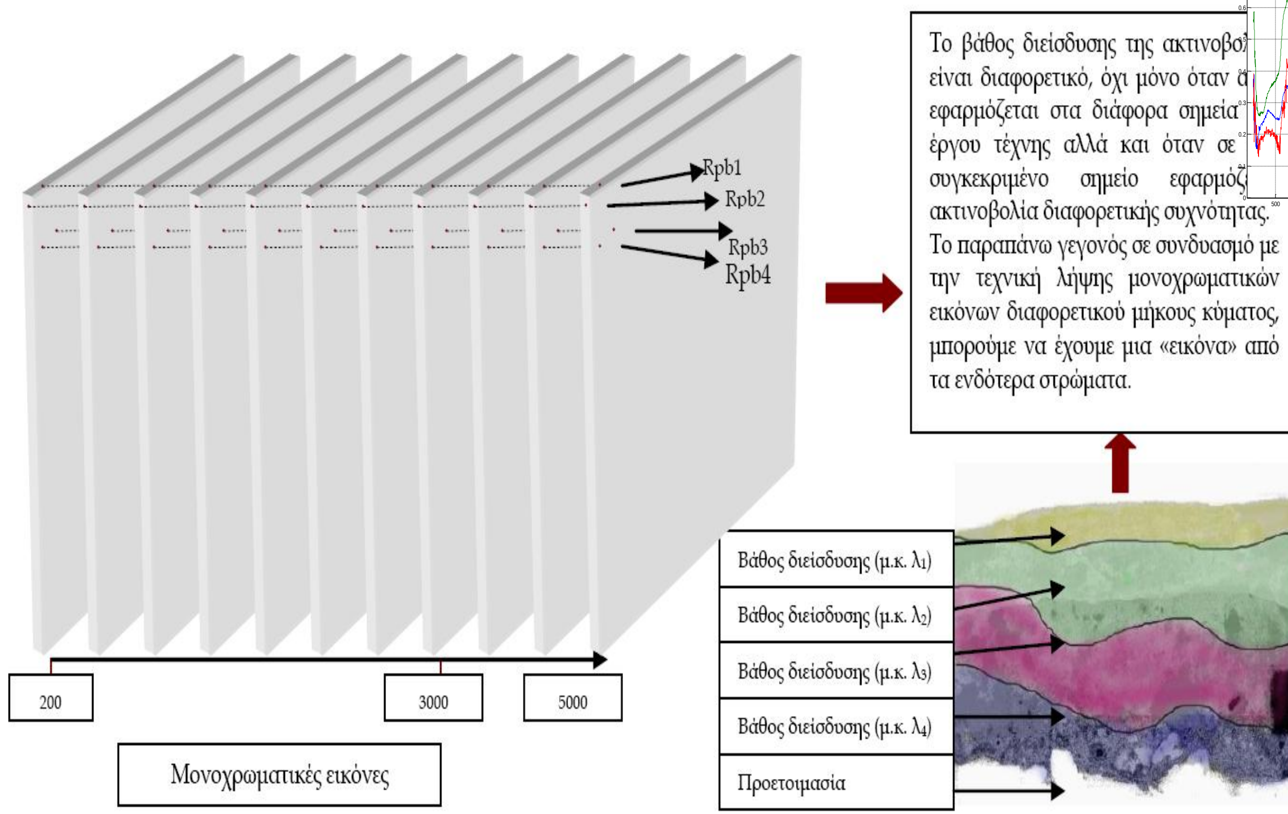
Combination of remote sensing – Reflectance imaging and spectroscopy with tomographic techniques for the identification of the "DNA"

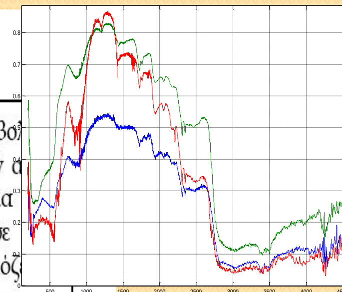


Multispectral imaging from 200-5000nm

Information acquisition from the under layers. It is not easy to estimate from which layer-depth this information is acquired…

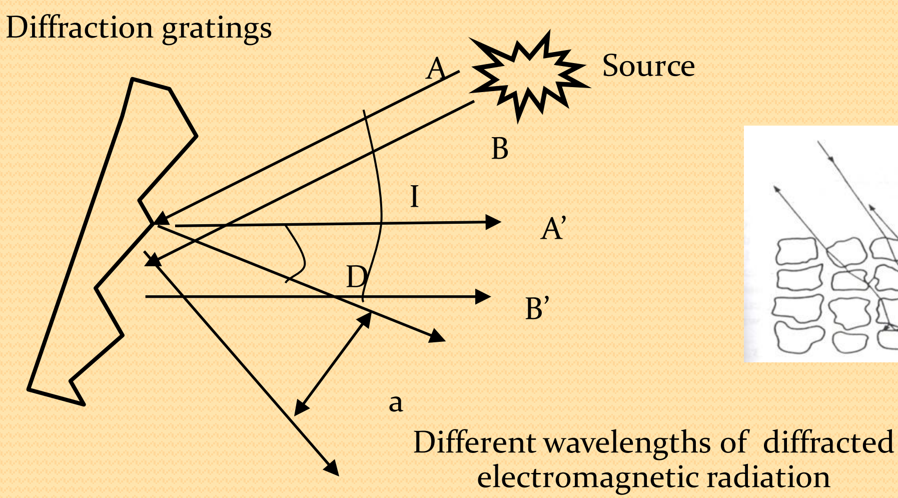


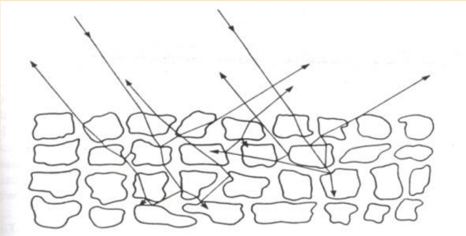


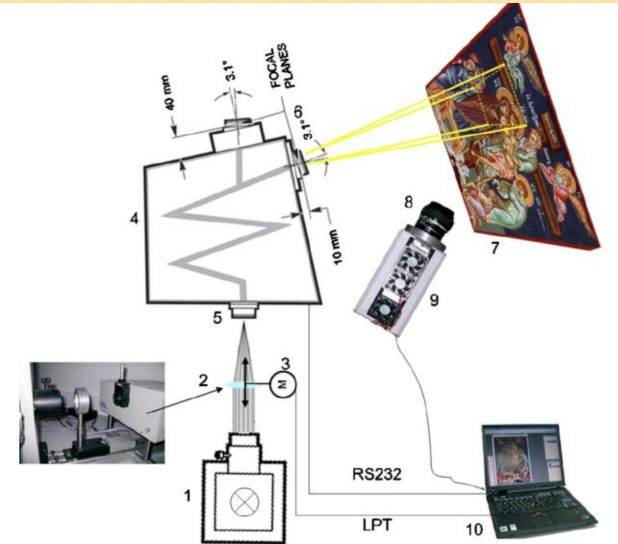


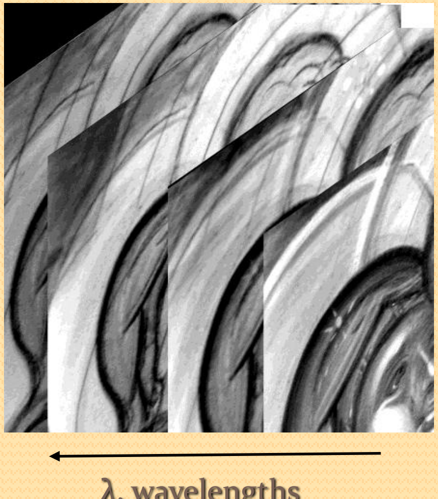
Multispectral imaging

Basic setup- principle







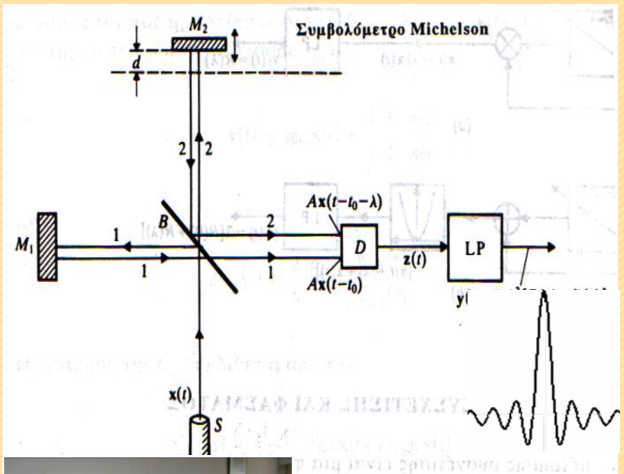


Multispectral materials mapping imaging

Basic setup- principle

Acquisition of multispectral images and spectra from 200 up to 5000nm

Interferometer



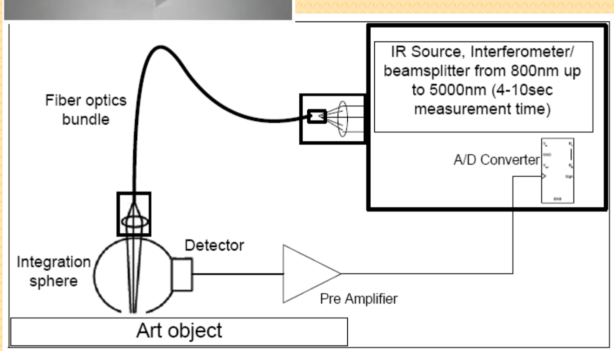
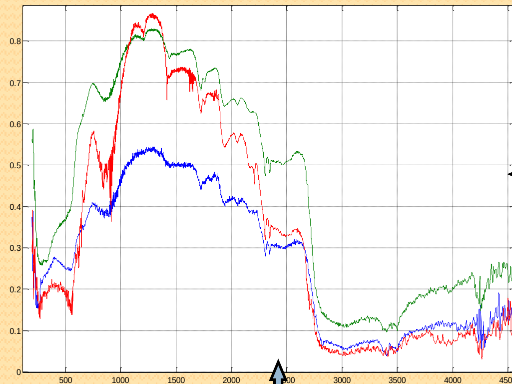
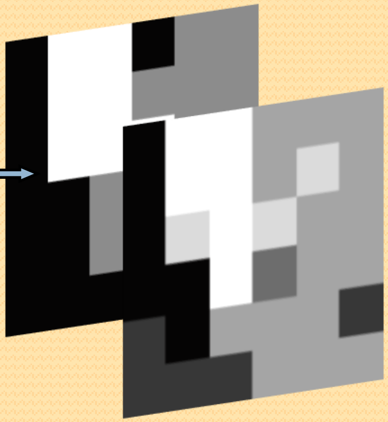
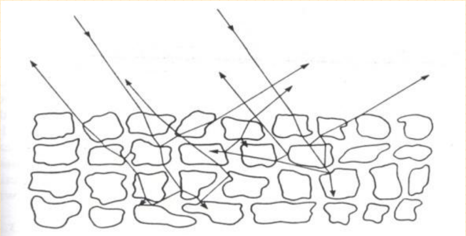


Fig. 15 nIR/mIR spectroscopic device basic digramme



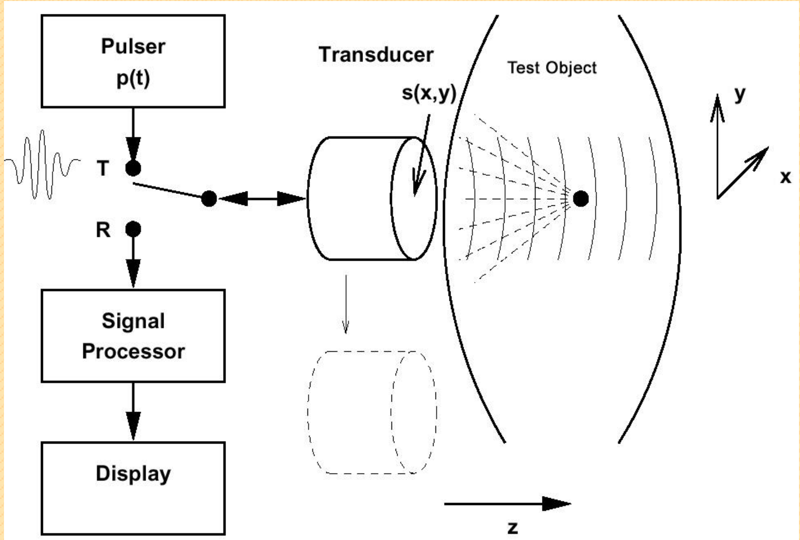


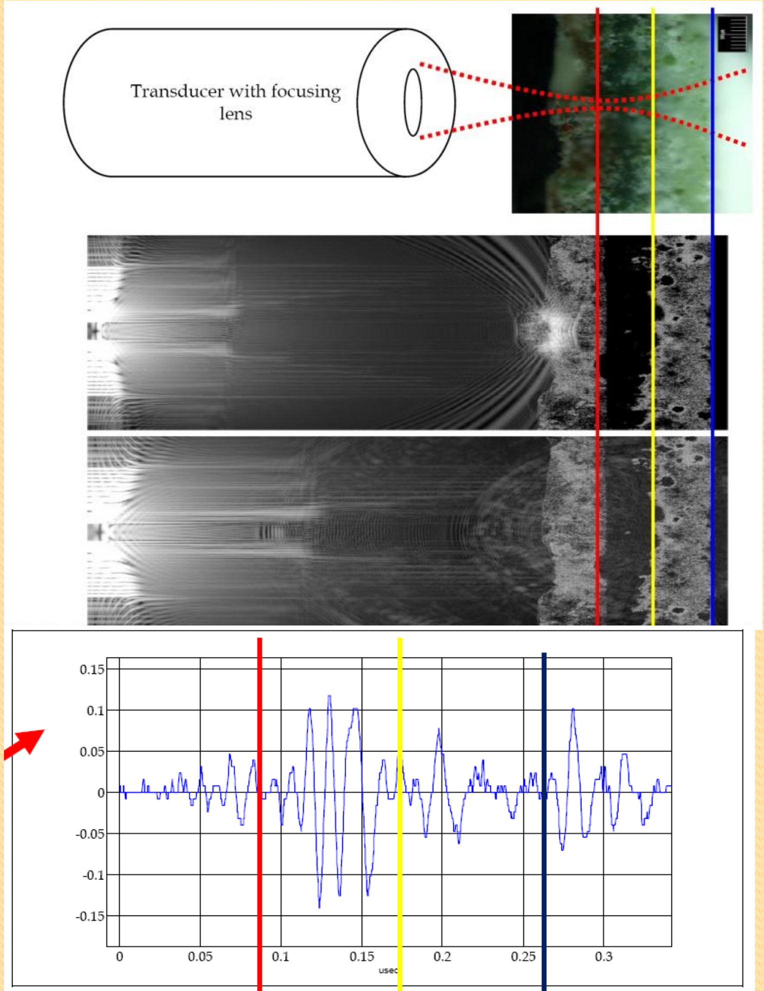


Acoustic – Ultrasonic Microscopy - Tomography

Basic setup- principle

Acquisition of a-c scan data from the multilayered structure using ultrasound frequencies higher than 100MHz

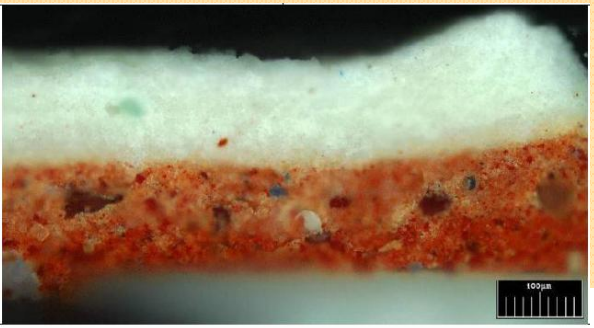


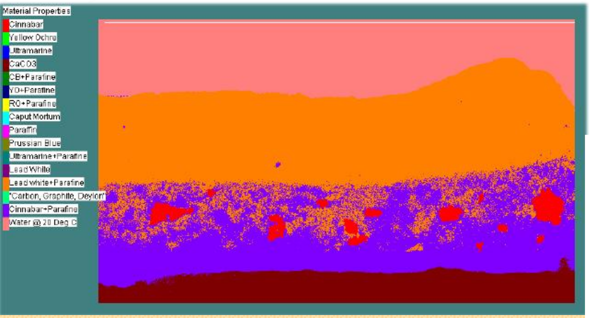


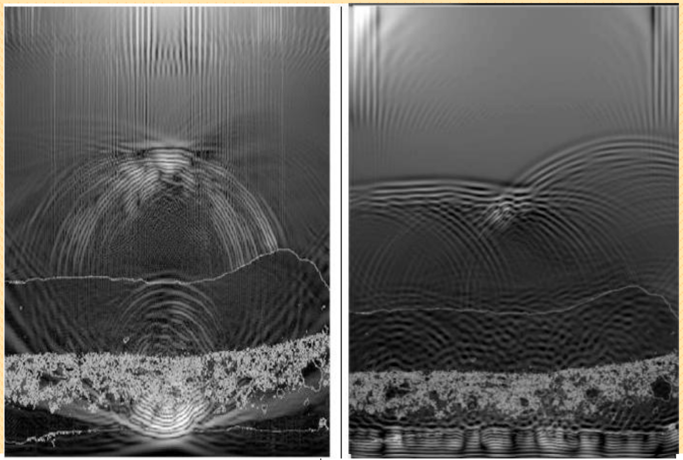
Acoustic – Ultrasonic Microscopy - Tomography

Basic setup- principle

Acoustic (ultrasound) wave propagation in stratigraphies of art objects

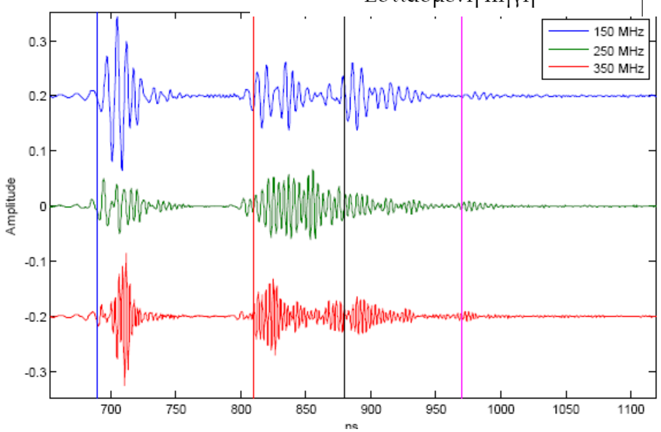


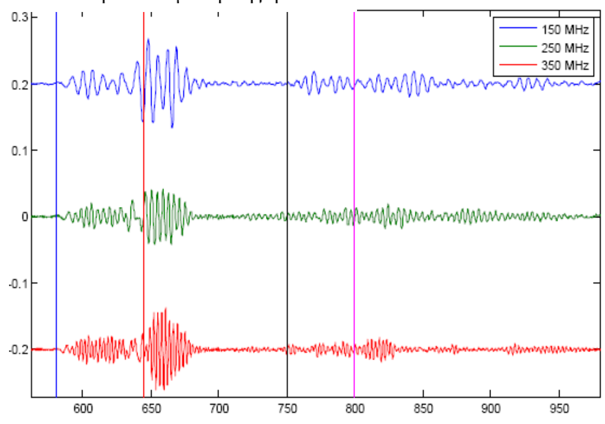


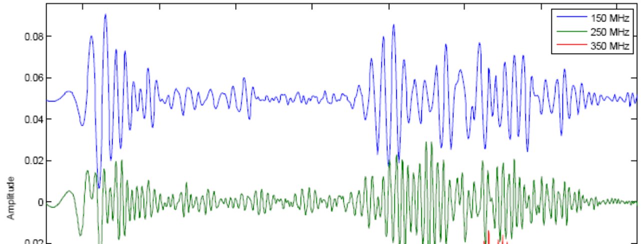


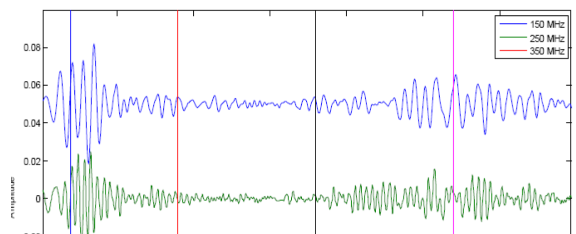
Εστιασμένη πηγή

Μη εστιασμένη πηγή









Multispectral imaging

- Surface

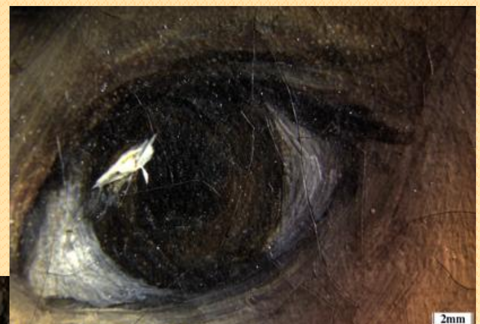
  Visible, UV Fluorescence

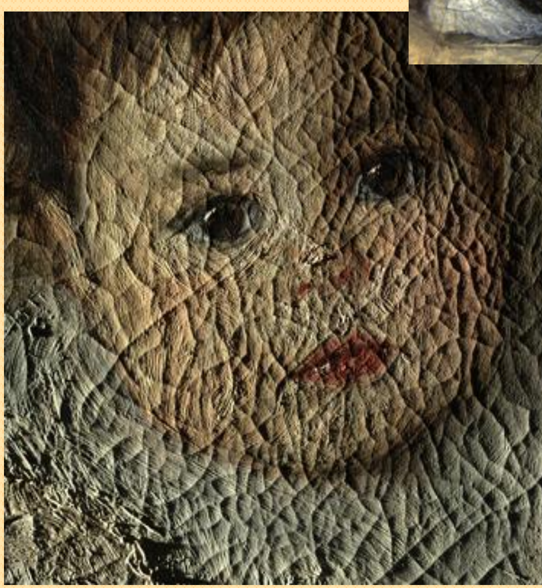
- From the internal structure (depth)

  IR Reflectograms, X-Radiographs

Multispectral imaging

- Surface

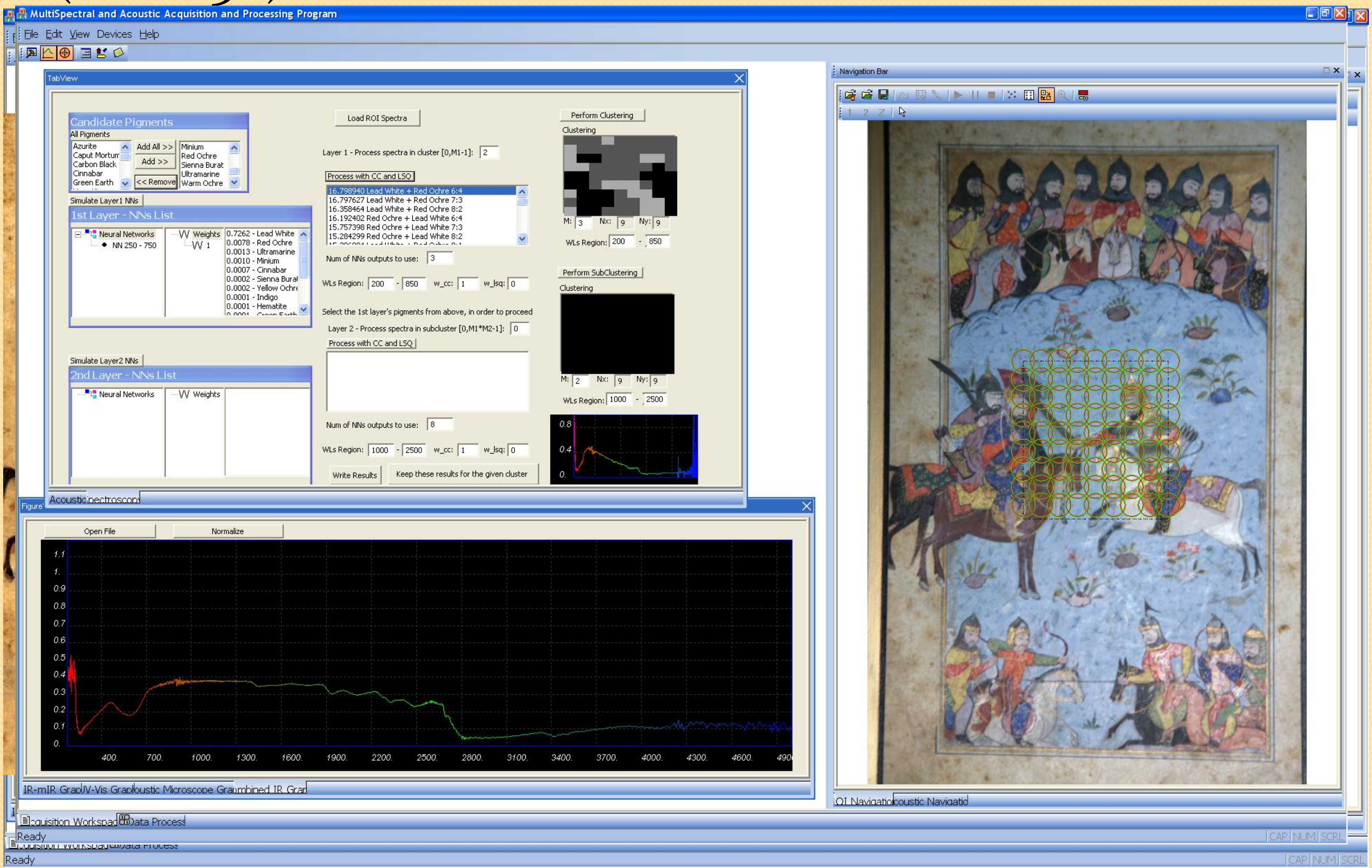




- From the internal structure (depth)

Multispectral mapping (spectroscopic) imaging

- (200-850)



Multispectral mapping (spectroscopic) imaging

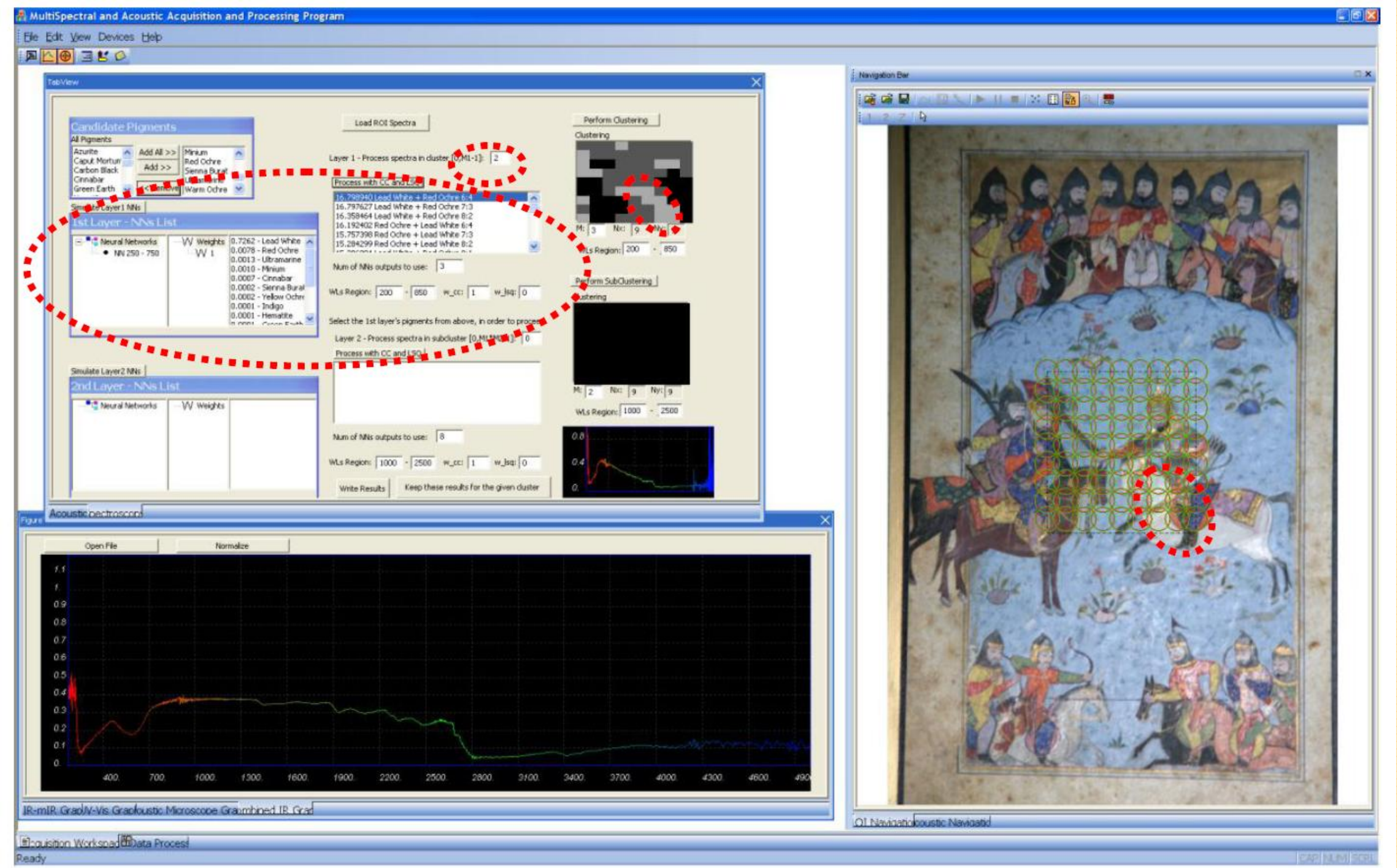


FIG. 59: The ROi in which the spectra were acquired. The clustering that was achieved in the spectral area between 200-850nm. The identification of the material for the cluster 2 indicated with the red dashed line on the ROI is Lead White and Lead white + Red Ochre (6:4)

Multispectral mapping (spectroscopic) imaging

- (

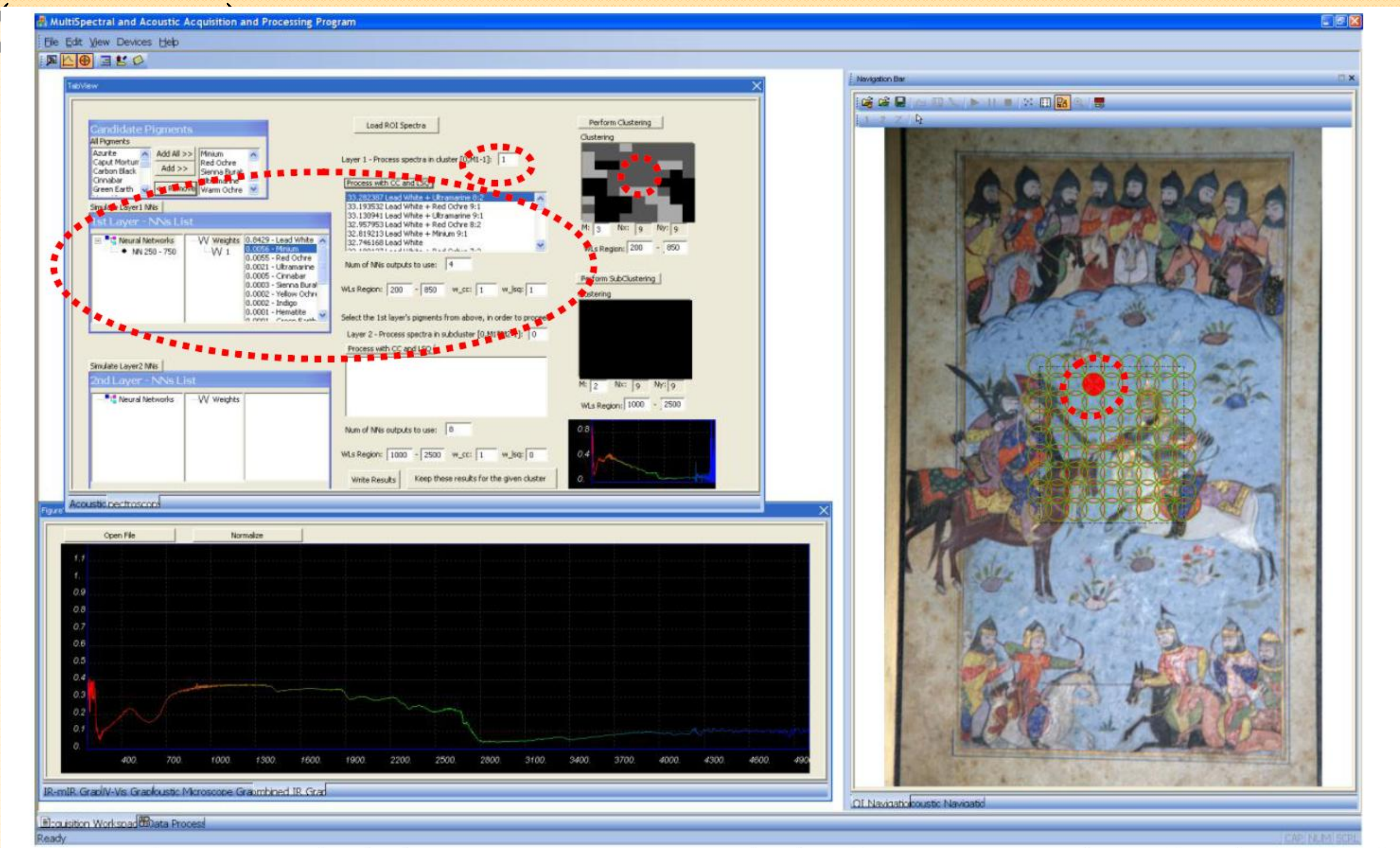
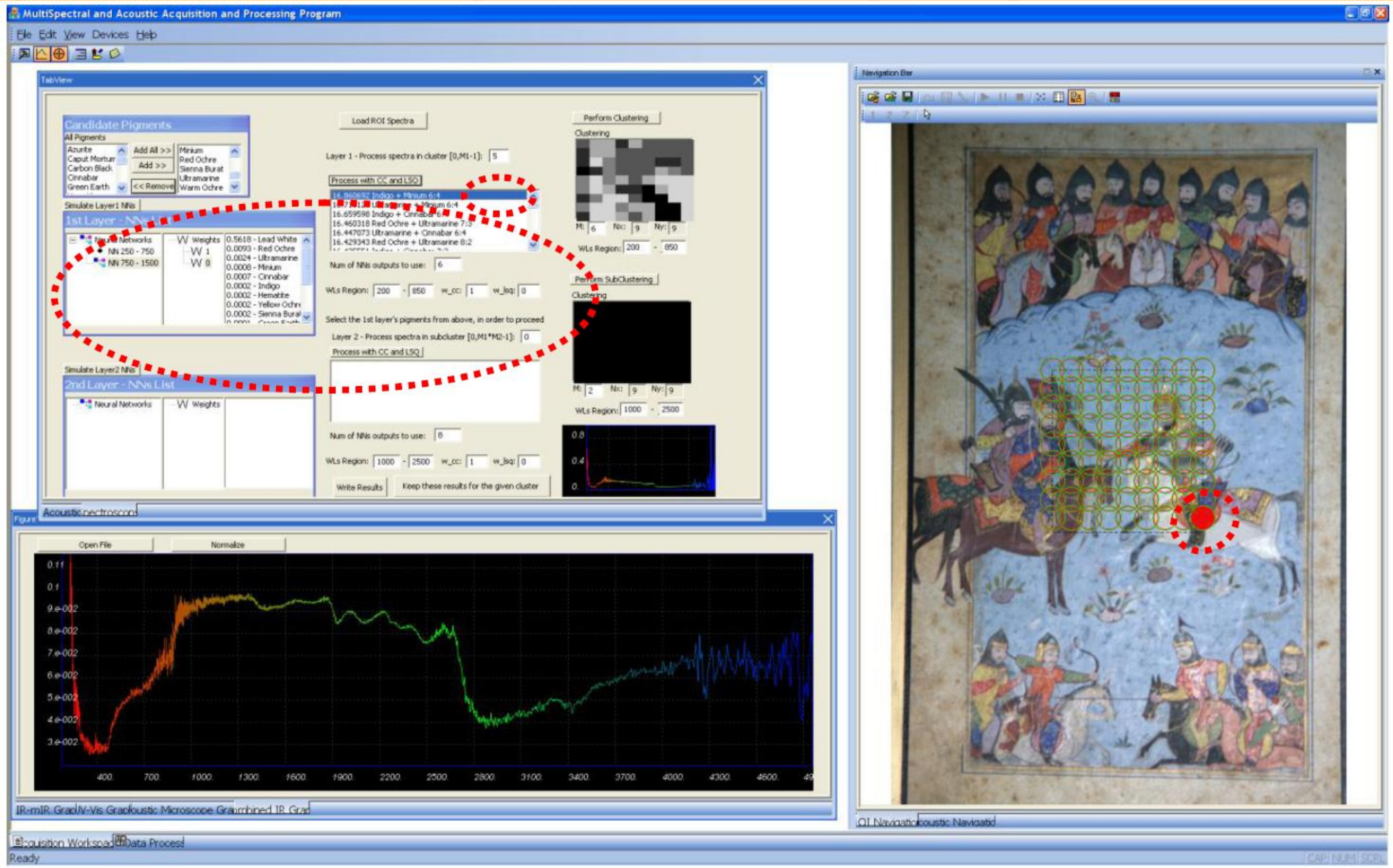


FIG. 60: The ROI in which the spectra were acquired. The clustering was achieved in the spectral area between 200-850nm. The identification of the material for the cluster 1 indicated with the red dashed line on the ROI is Lead White and Ultramarine (8:2) and with high probability also Lead white and Red Ochre (9:1)

Multispectral mapping (spectroscopic) imaging

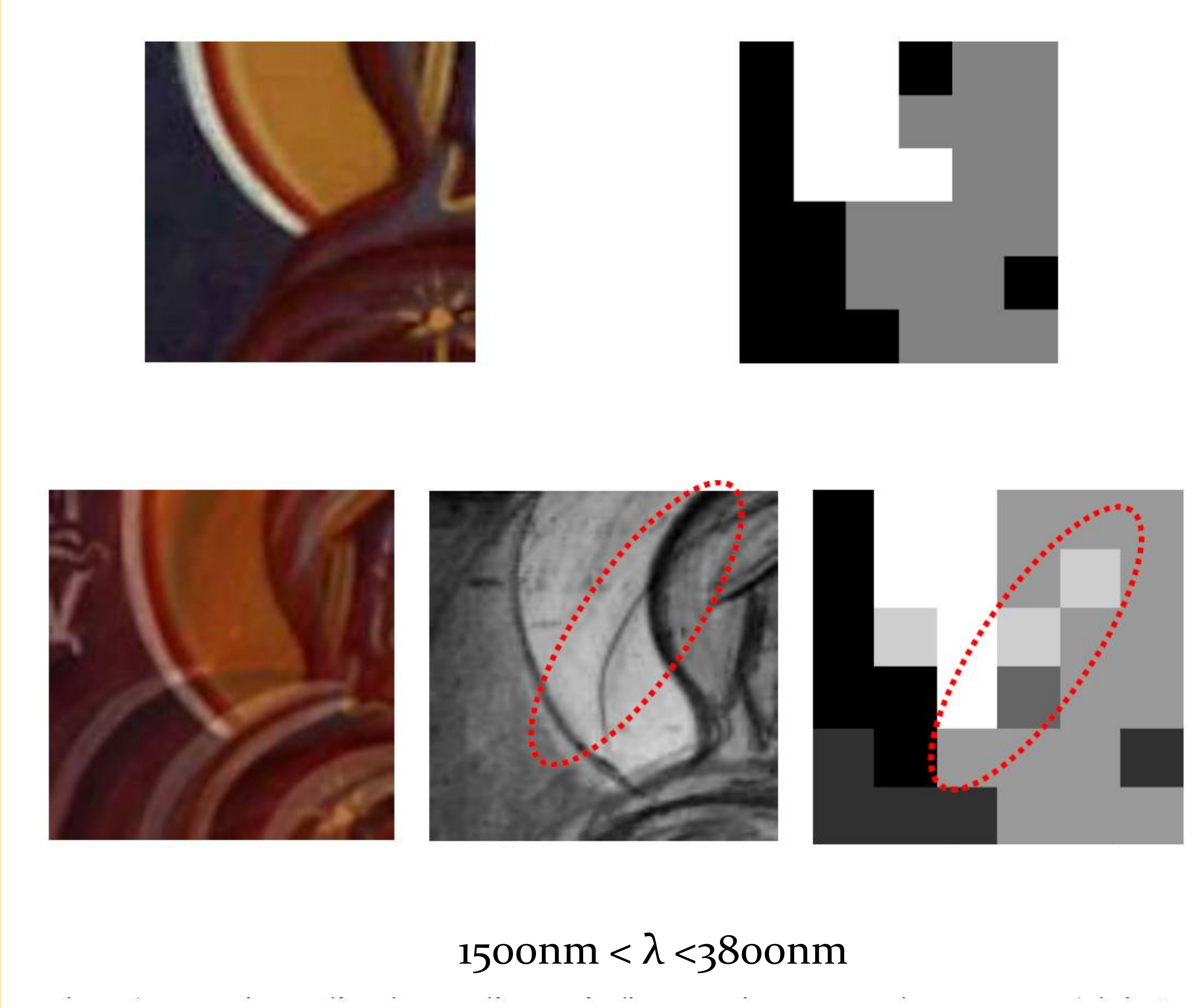
- (



The “blue” and the orange on the horses the algorithm identify Indigo and Minium with high probability and proportion (6:4). Second choice also is the Ultramarine and Minium (6:4). These results are in agreement with the results of raman analysis

Multispectral mapping (spectroscopic) imaging

Clustering of the materials in a portable icon

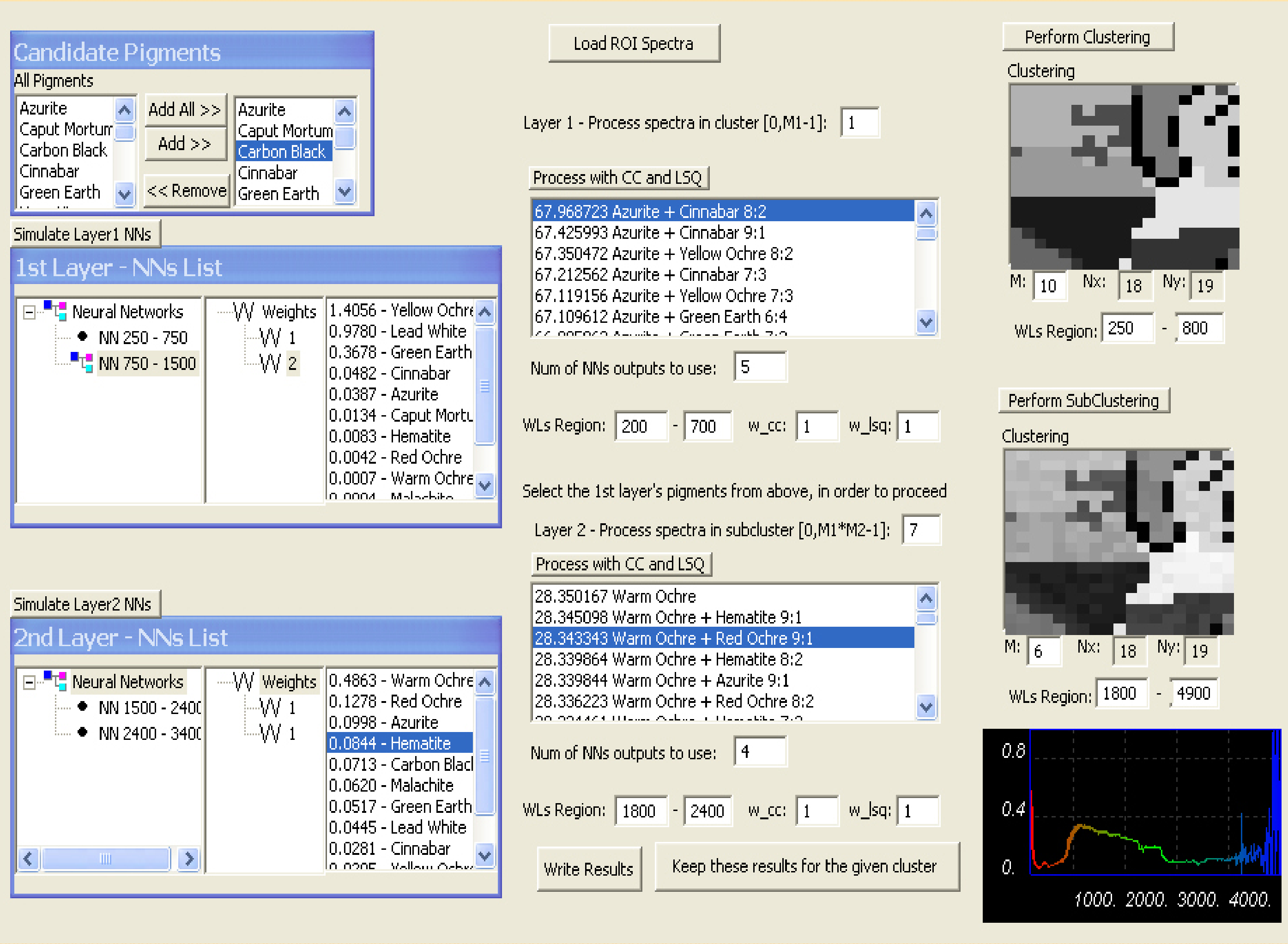


Multispectral mapping (spectroscopic) imaging

Clustering of the materials in a portable icon

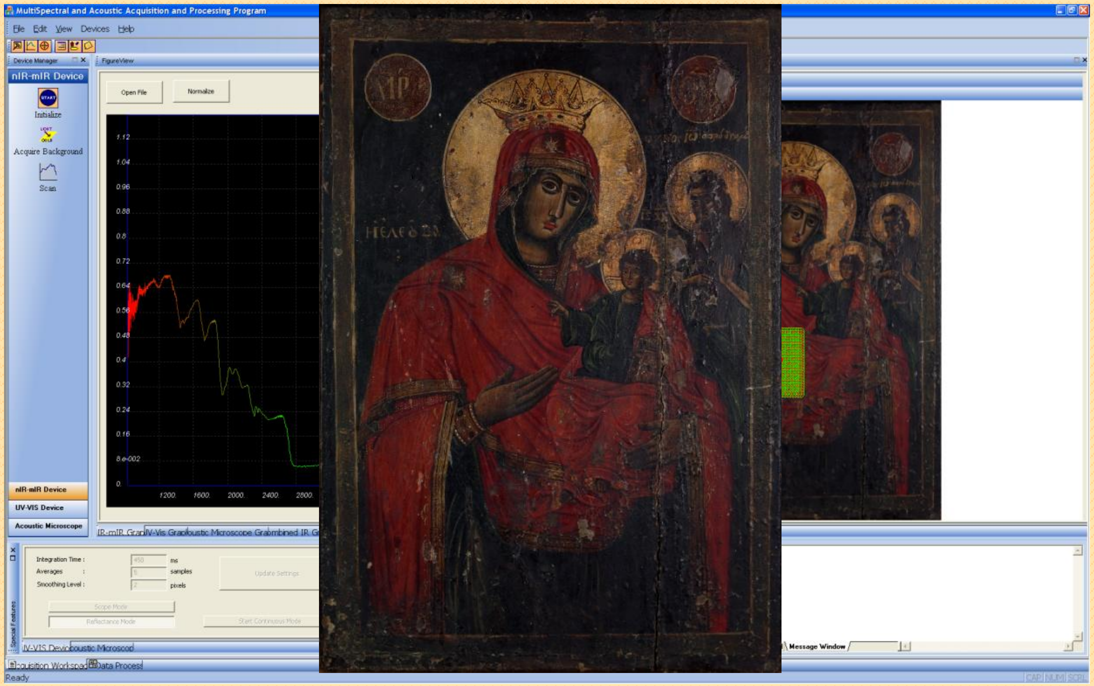
250 nm < λ <800 nm

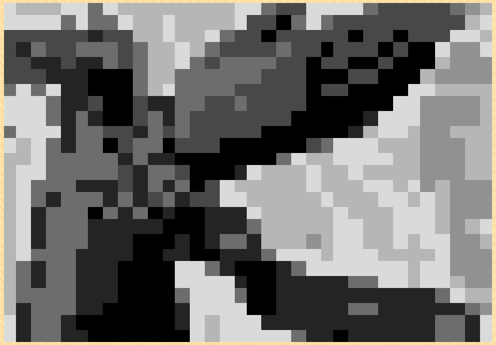
1800 nm < λ <2400 nm



Multispectral mapping (spectroscopic) imaging

Clustering of the materials in a portable icon using radiation in different wavelengths from UV-mIR

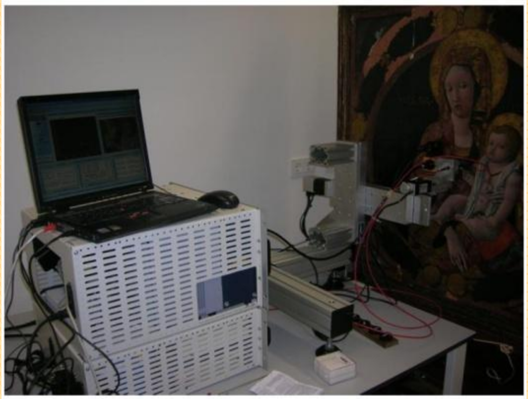




1500nm < λ <3800nm

Multispectral imaging and mapping (spectroscopic) imaging

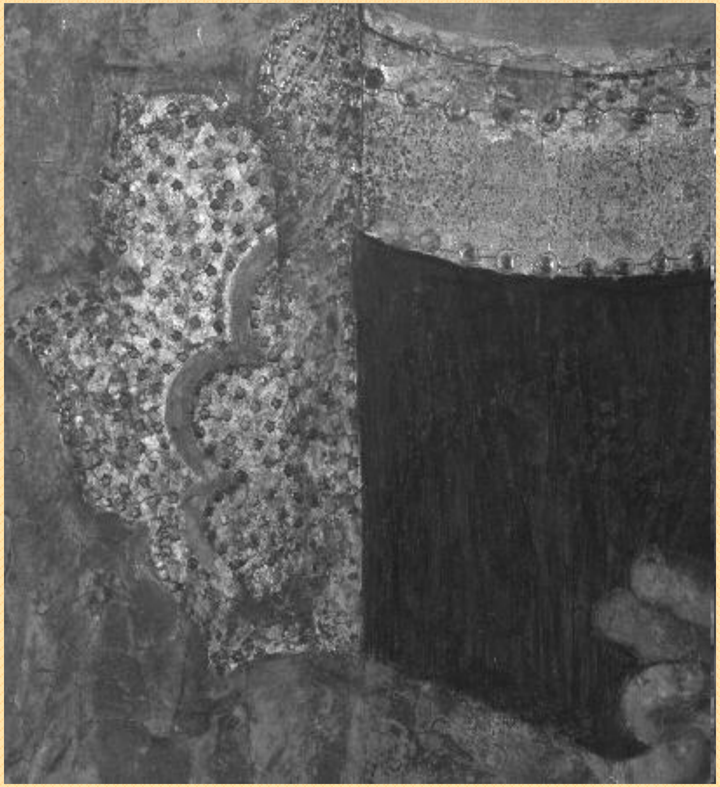
- (250-850) -- (1000-1200) -- (1700-2500) – (1700-3800)nm

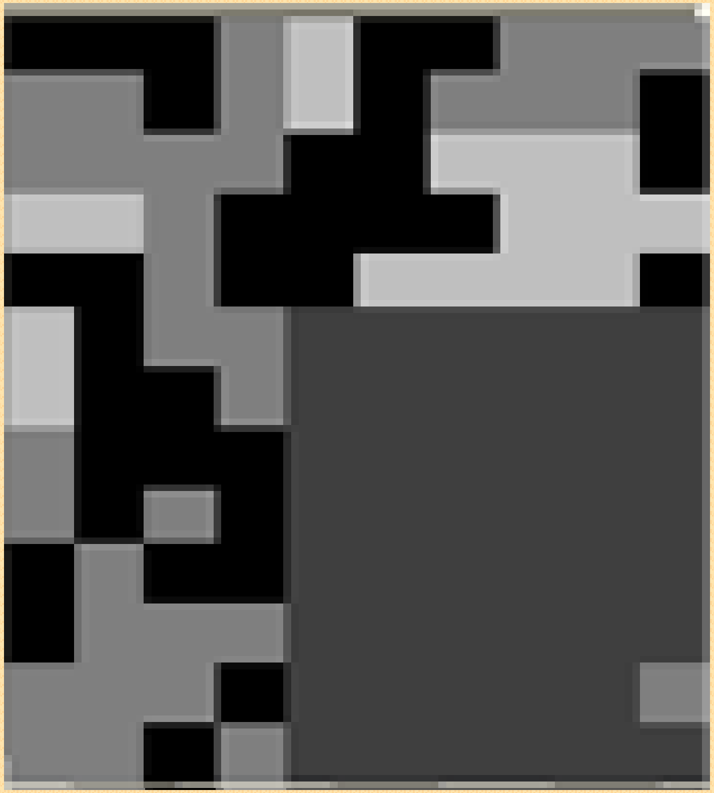


Results from combined actions in the frame of InfrArtSonic and EU-ARTECH projects

Multispectral imaging and mapping (spectroscopic) imaging

- (200-850) -- (1000-1200) -- (1700-2500) – (1700-3800)nm

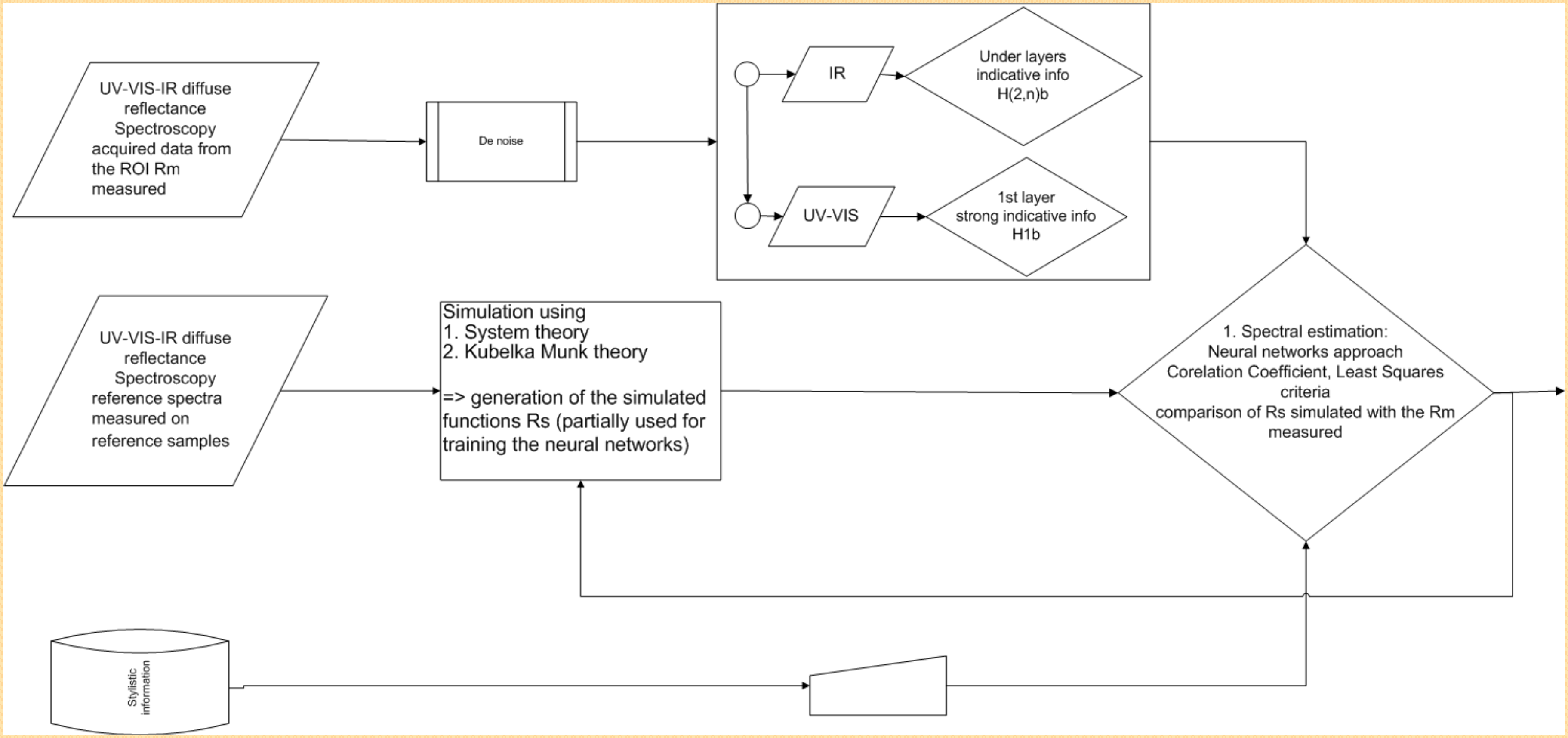




Results from combined actions in the frame of InfrArtSonic and EU-ARTECH projects

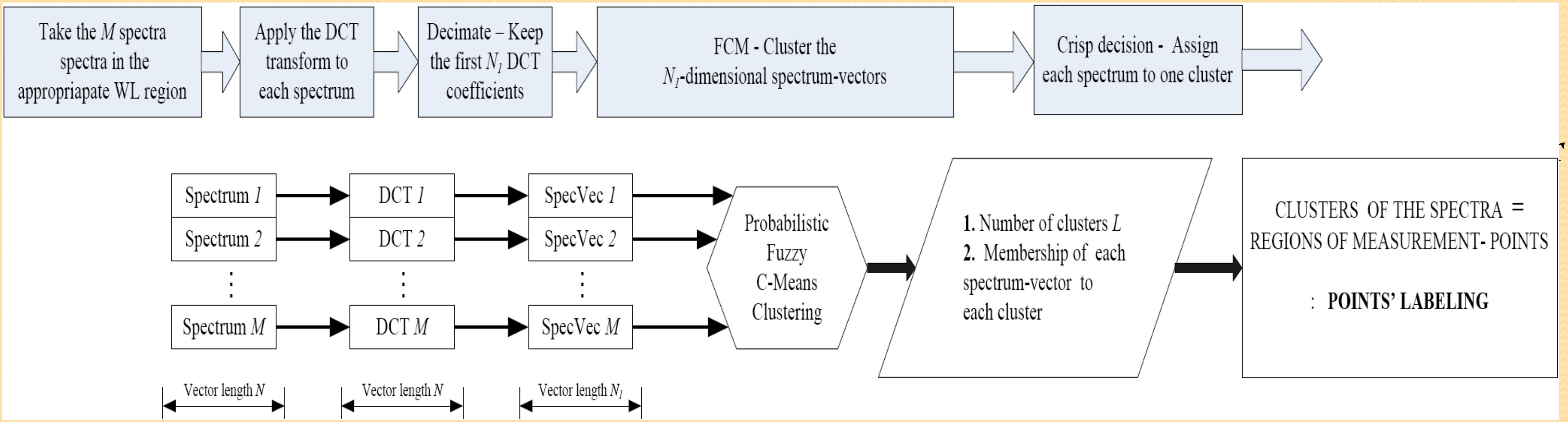
Multispectral imaging and mapping (spectroscopic) imaging

The effort to identify the materials in a 3D multi layered structure like the pint layers of art objects using NDT techniques is not easy.
This is an artist – human creation and consequently is a stochastic problem to be solved mainly related to the estimation-evaluation- processing of the data.
The use of artificail intelligence techniques which can be appropriately trained according to the problem that we are each time phasing is a solution...



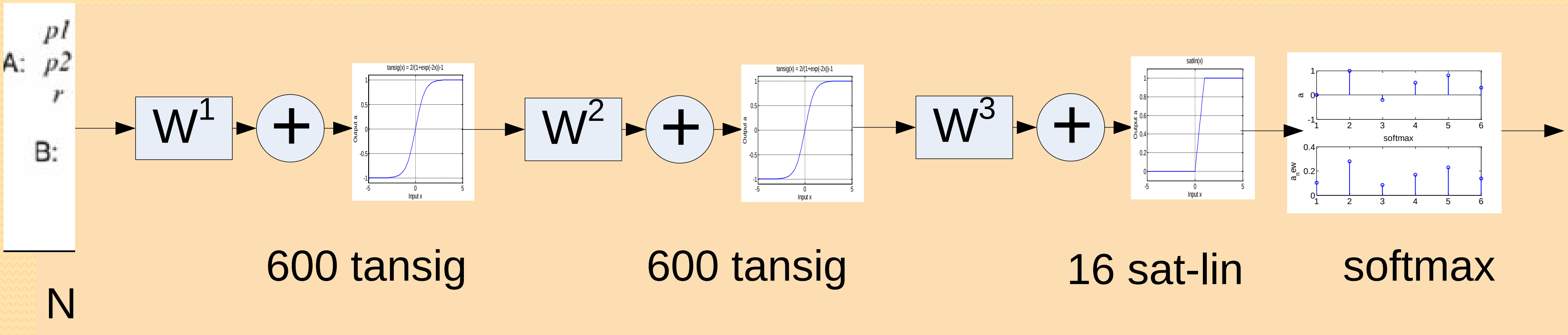
Multispectral imaging and mapping (spectroscopic) imaging

Clustering of the spectra



Multispectral imaging and mapping (spectroscopic) imaging

Neural Networks

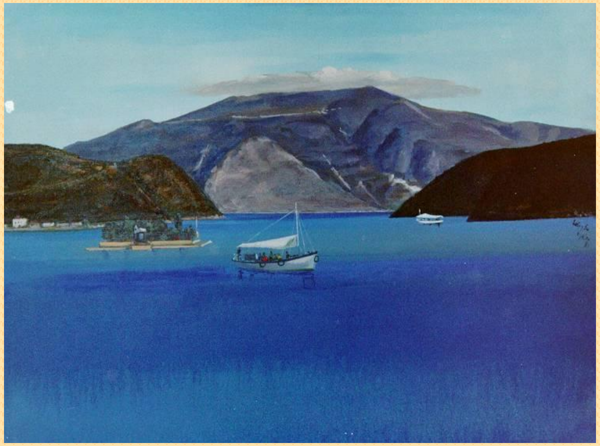


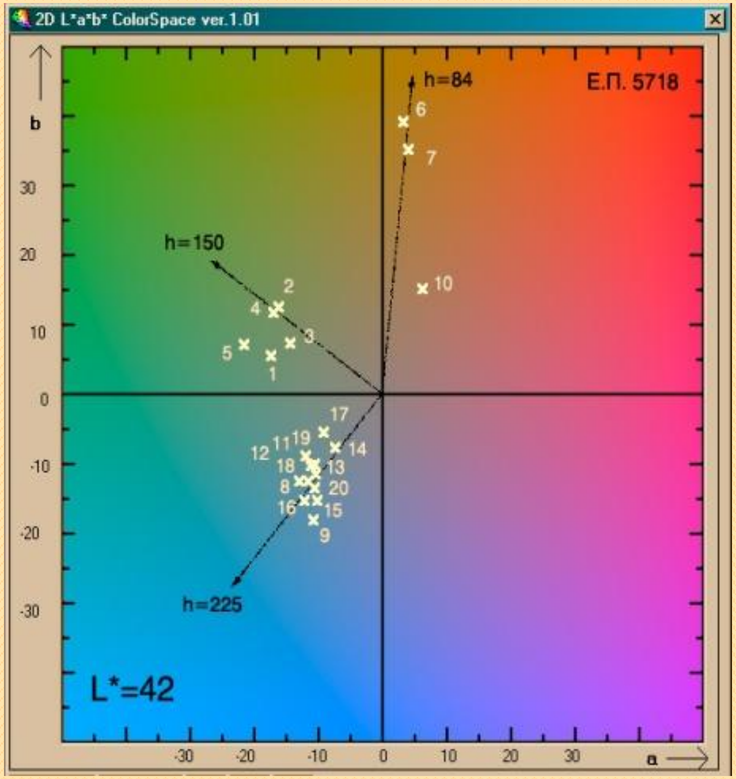
Input:
Κατά την ταυτοποίηση του δευτέρου στρώματος, η στοιχειοσειρά A περιέχει τους δείκτες p1, p2 των χρωστικών ουσιών στο πρώτο στρώμα, συν την αναλογία μίξης τους r και το διάνυσμα φάσματος B είναι το διάνυσμα φάσματος X[v] (στην κατάλληλη περιοχή μηκών κύματος)
600 neurons in each neural network layer (16 are the refernce pigments spectra)

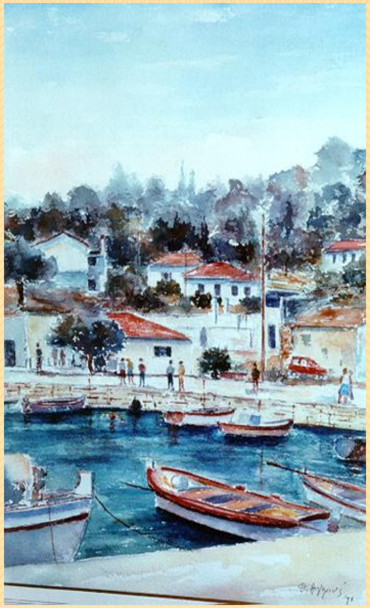
Output:
Το παραγόμενο διάνυσα T[m] είναι μήκους M=16, όπου το M είναι ο αριθμός των υποψηφίων χρωστικών ουσιών προς ταυτοποίηση. Το στοιχείο T[m] του διανύσματος αντιπροσωπεύει την αναλογία της χρωστικής ουσίας με το δείκτη m.

Training method: Resilient backpropagation

Colorimetric … comparison with other paintings of the same creator



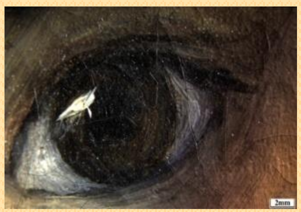


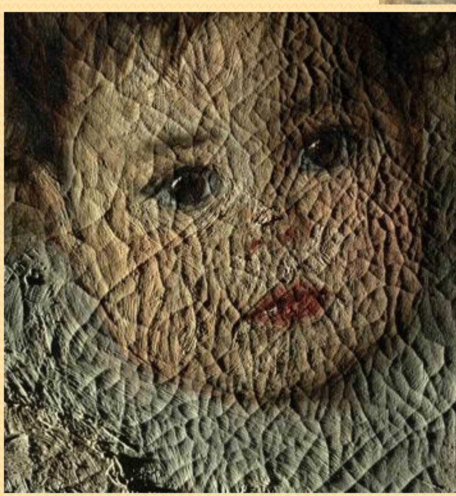


Paintings from National Gallery of Athens, Parthenis, Vasileiou ,…

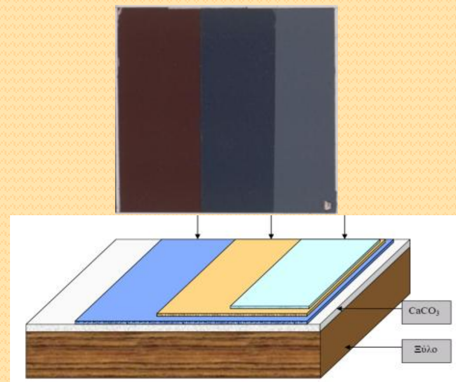
Macro and micro strucutre of the surface - roughness

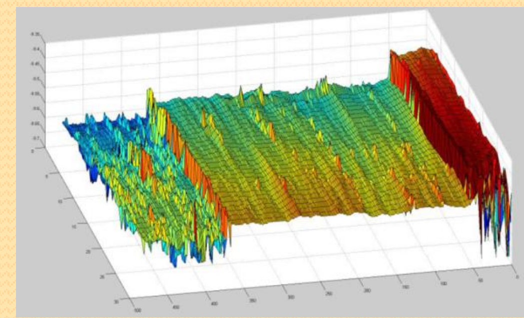
- Macro information related to cracks network

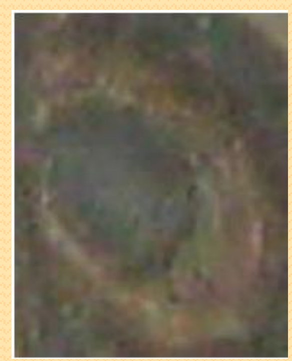


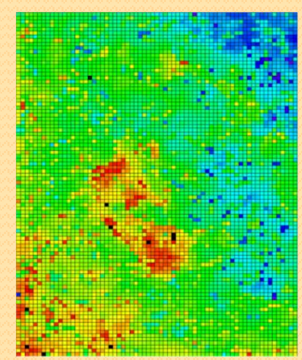


- Micro information related to roughness (stratigraphy and eye of the wall painting)

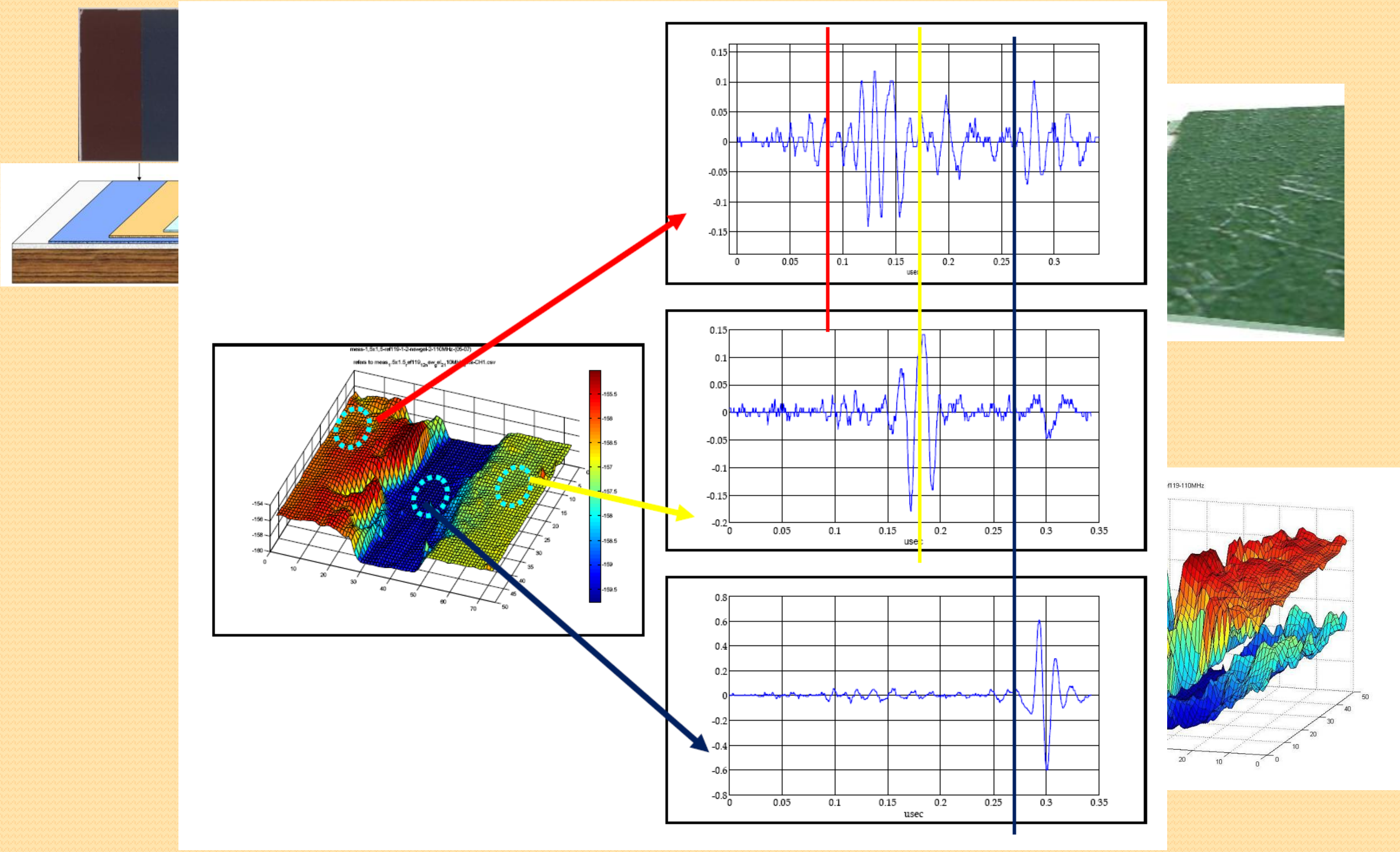




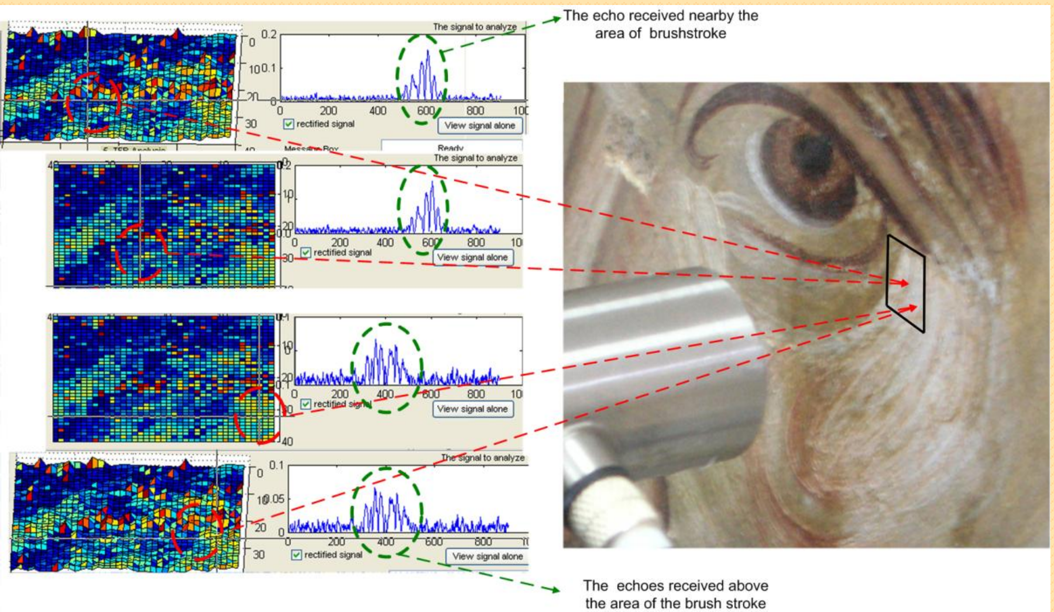


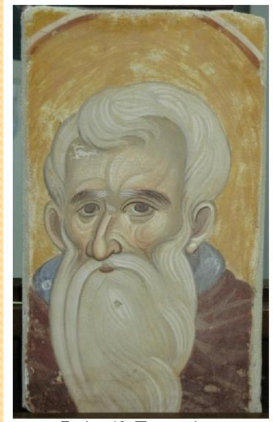


3D reconstruction of the stratigraphic structure



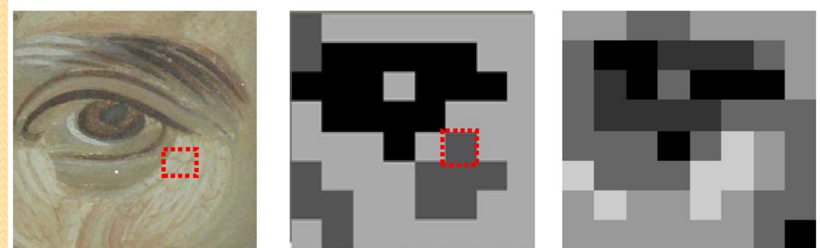
3D reconstruction of the stratigraphic structure including all the information (materials and structure)





Εικόνα 49: Προσομοίωση τοιχογραφίας

Εικόνα 50: Εικόνα στην υπέρυθρη περιοχή του φάσματος (από 1500nm έως 5000nm) από την προσομοίωση της τοιχογραφίας που εικονίζεται στην *Εικόνα 49*



Σχήμα 193: Η ομαδοποίηση που επιτεύχθηκε και αντίστοιχη περιοχή της εικόνας για το επιφανειακό στρώμα. Δεξιά δίνονται τα φάσματα της κάθε ομάδας (1η ομάδα είναι η σημειωμένη με μαύρο και 3η με το πιο υψηλό πίπεδο του γκρίζου). Επίσης παρουσιάζεται η ομαδοποίηση που επιτεύχθηκε ορίζοντας την ομαδοποίηση σε 5 ομάδες

3D reconstruction of the stratigraphic structure

Acoustic (ultrasound) wave propagation in the reference stratigraphies using Finite Difference Method for the optimal design of the final system (operation frequency, acoustic lens, …)

$$\rho \frac{\partial^2 \tilde{u}}{\partial^2 t} = \left[\lambda + \mu + \phi \frac{\partial}{\partial t} + \frac{\eta}{3} \frac{\partial}{\partial t} \right] \nabla(\nabla \tilde{u}) + \left[\mu + \eta \frac{\partial}{\partial t} \right] \nabla^2 \tilde{u}$$

Where:

$\vec{u} = \begin{bmatrix} u_x \\ u_y \\ u_z \end{bmatrix}$ is the displacements of particles of the material in three dimensions [m]

ρ = density of the material [kg/m^3]

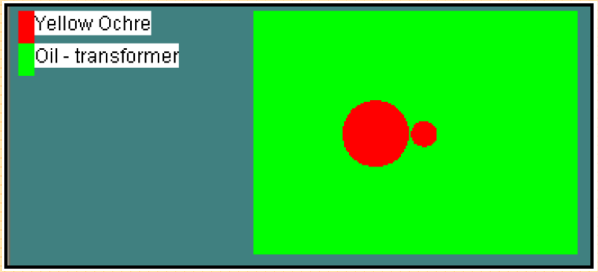
λ, μ = first and second regularly Lamé [N/m^2]

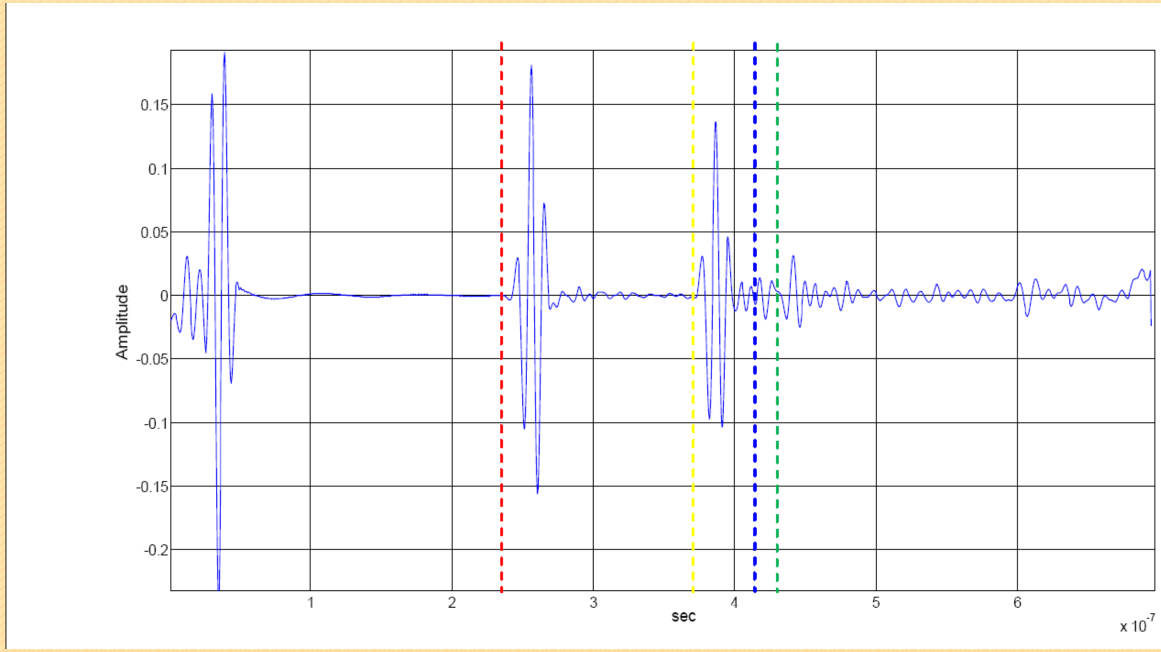
η = shear viscosity [N*s /m^2]

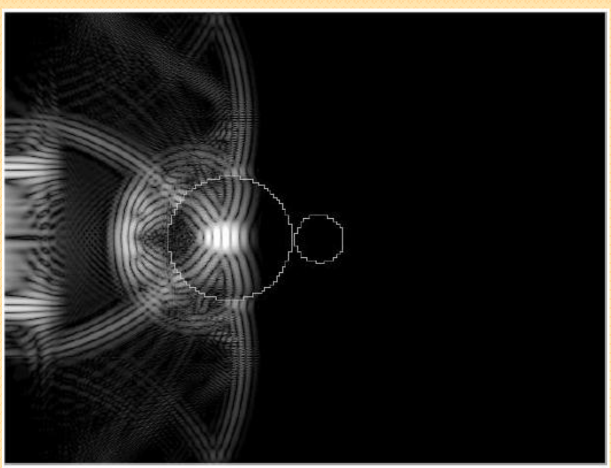
φ = bulk viscosity [N*s /m^2],

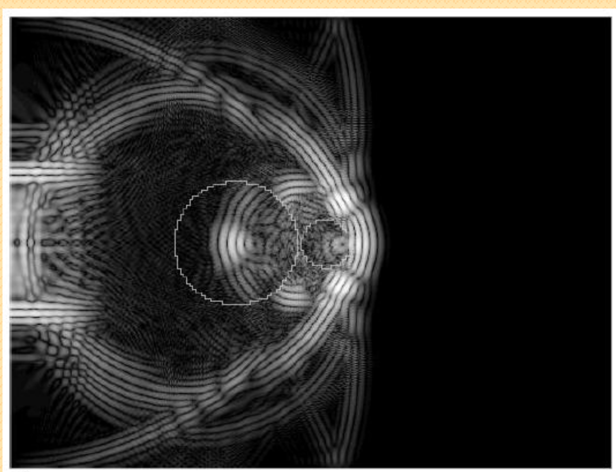
3D reconstruction of the stratigraphic structure

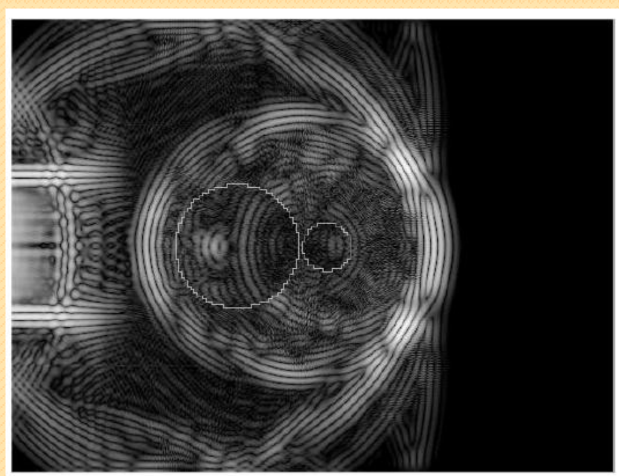
Acoustic (ultrasound) wave propagation in the reference stratigraphies using Finite Difference Method





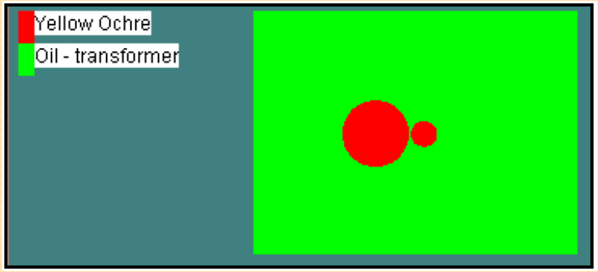


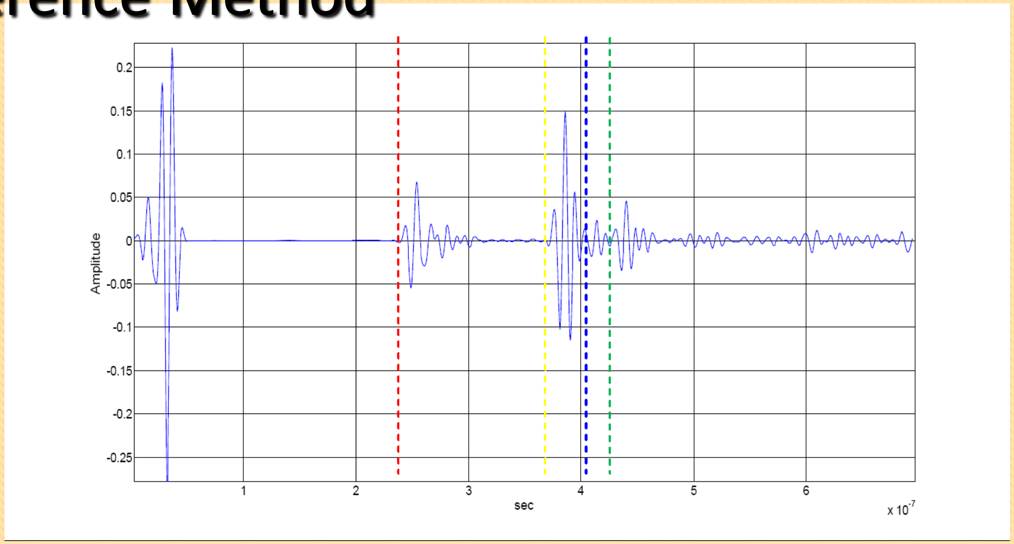


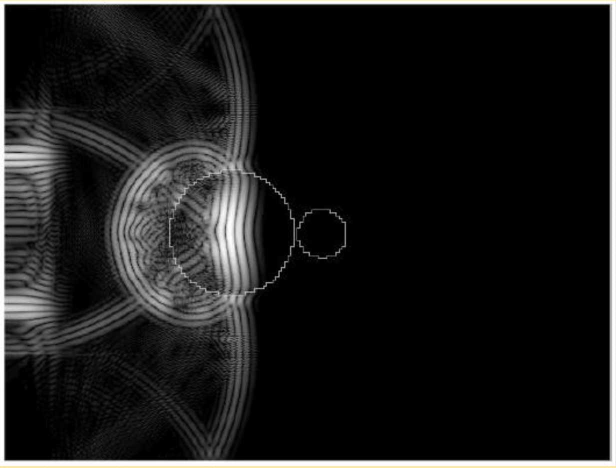


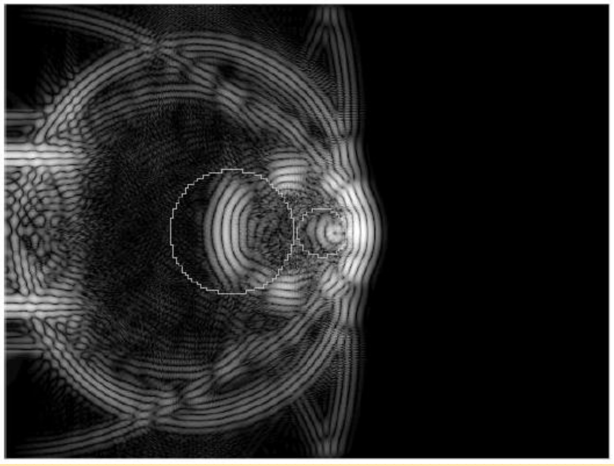
3D reconstruction of the stratigraphic structure

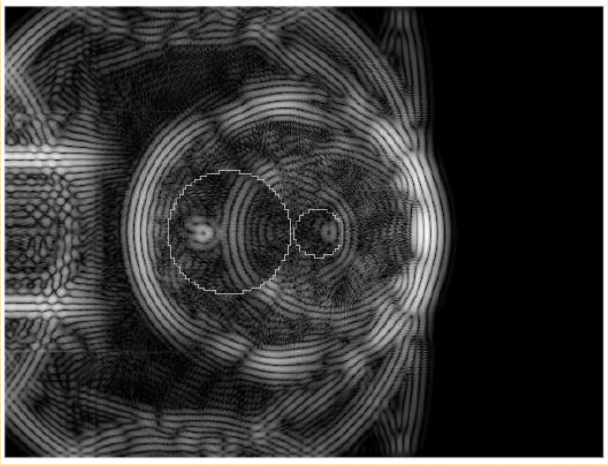
Acoustic (ultrasound) wave propagation in the reference stratigraphies using Finite Difference Method







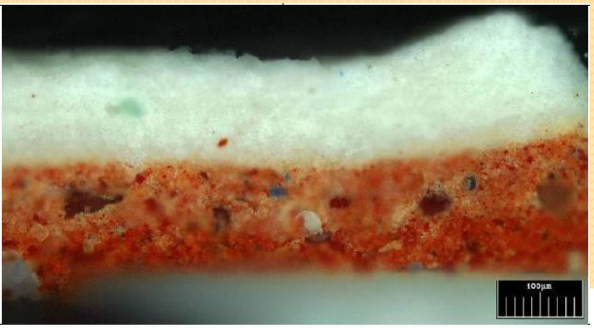


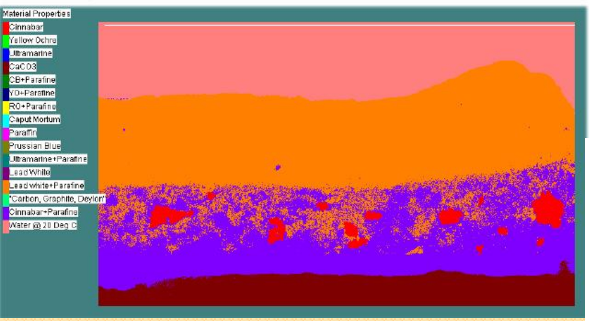


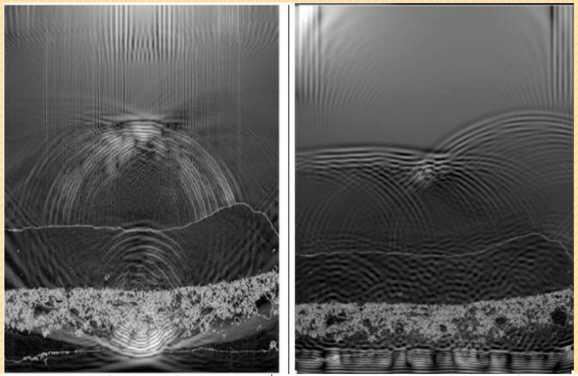
3D reconstruction of the stratigraphic structure

Acoustic (ultrasound) wave propagation in the reference stratigraphies using Finite Difference Method

Reference No 115

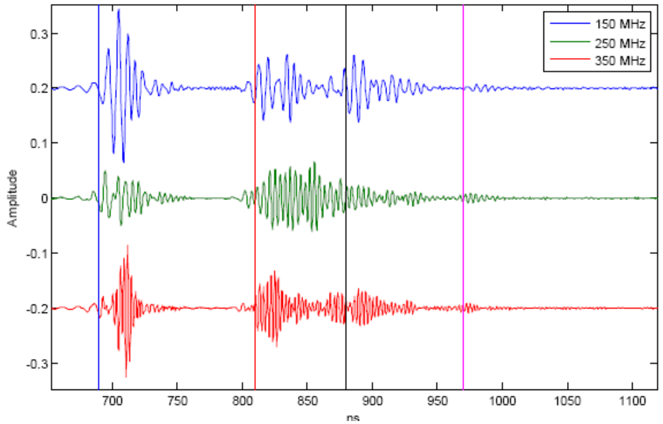


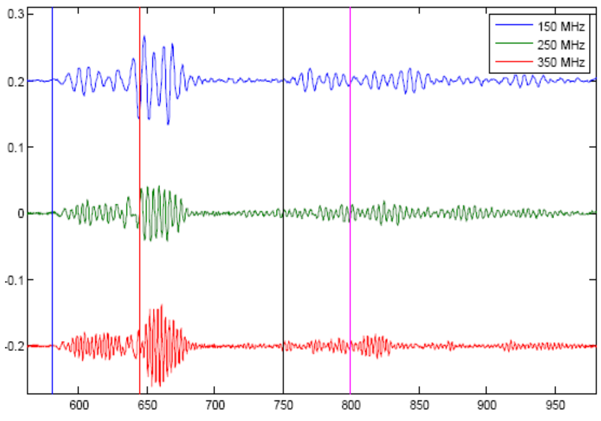


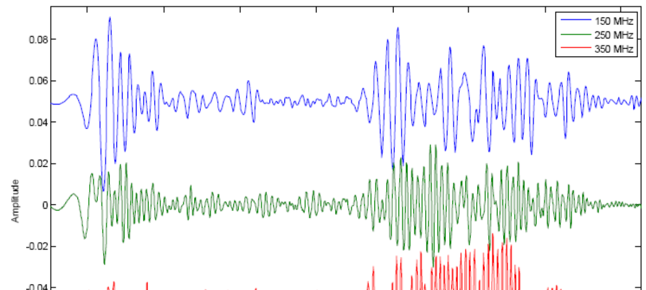


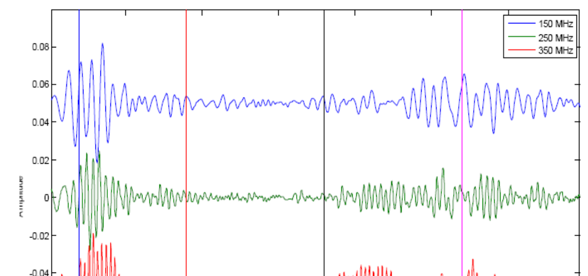
Εστιασμένη πηγή

Μη εστιασμένη πηγή





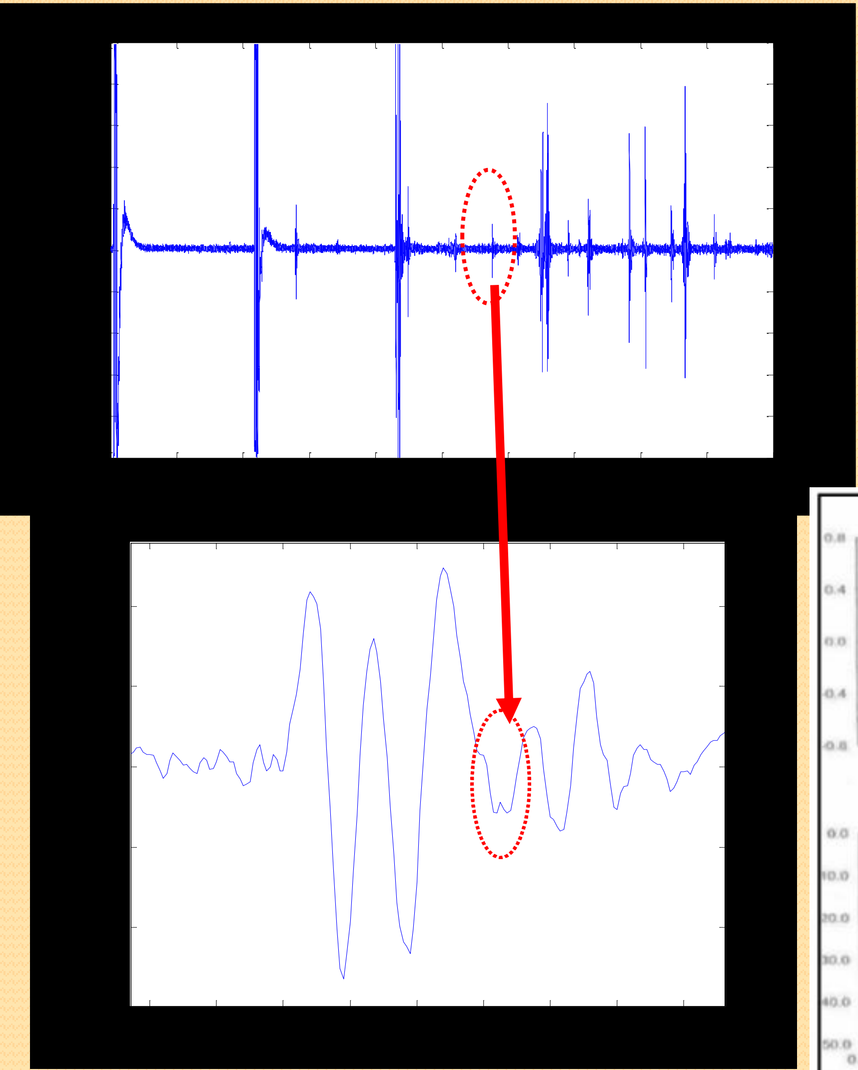


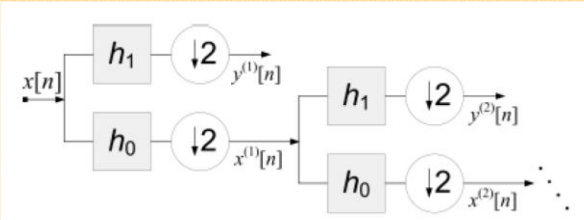


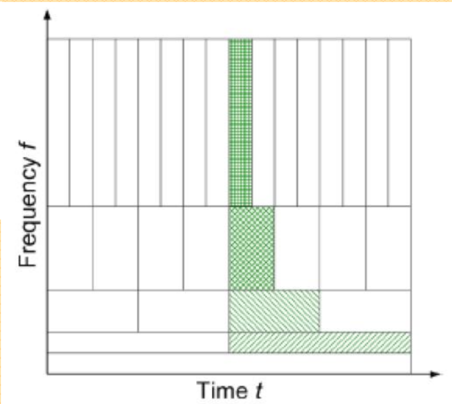
3D reconstruction of the stratigraphic structure

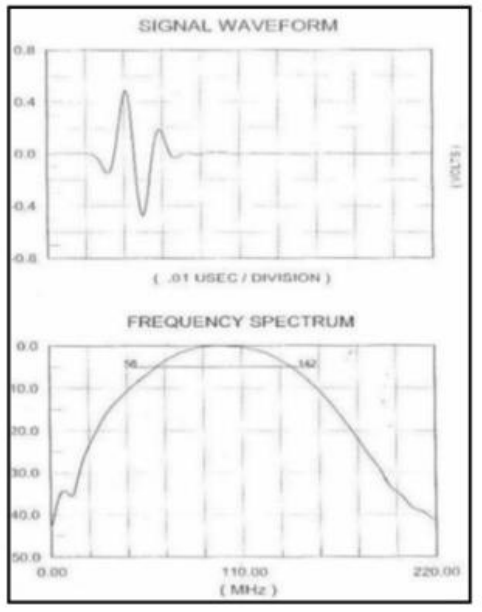
Signal Processing Methods

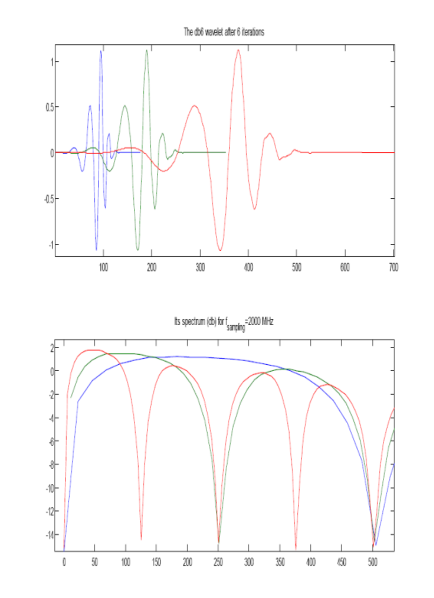
Time Frequency representations, Wavelet Transf., Hilbert Huang











Storage supporting the evaluation and the correlation of the information acquired from the same or similar objects

The Graphical Interface of the Database allows complete **browsing** and **inserting** of new data in the entire database schema.

It allows **navigation** in the images and spectra with **several "processing"** capabilities

Storage supporting the evaluation and the correlation of the information acquired from the same or similar objects

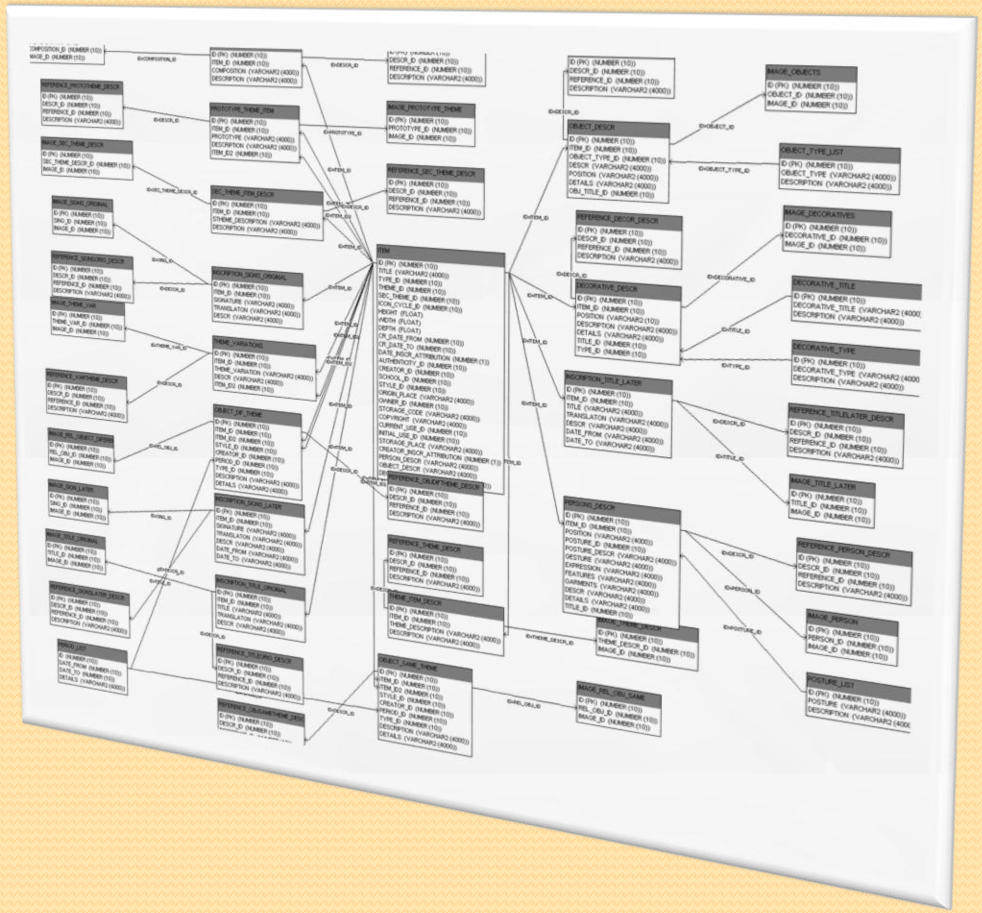
Database schema was created in accordance to the data description.
Images are stored with the *Oracle™* technology.

The schema consists of:

- ~250 Tables
- ~40 Thesaurus Tables
- ~50 Image Tables

And contains:

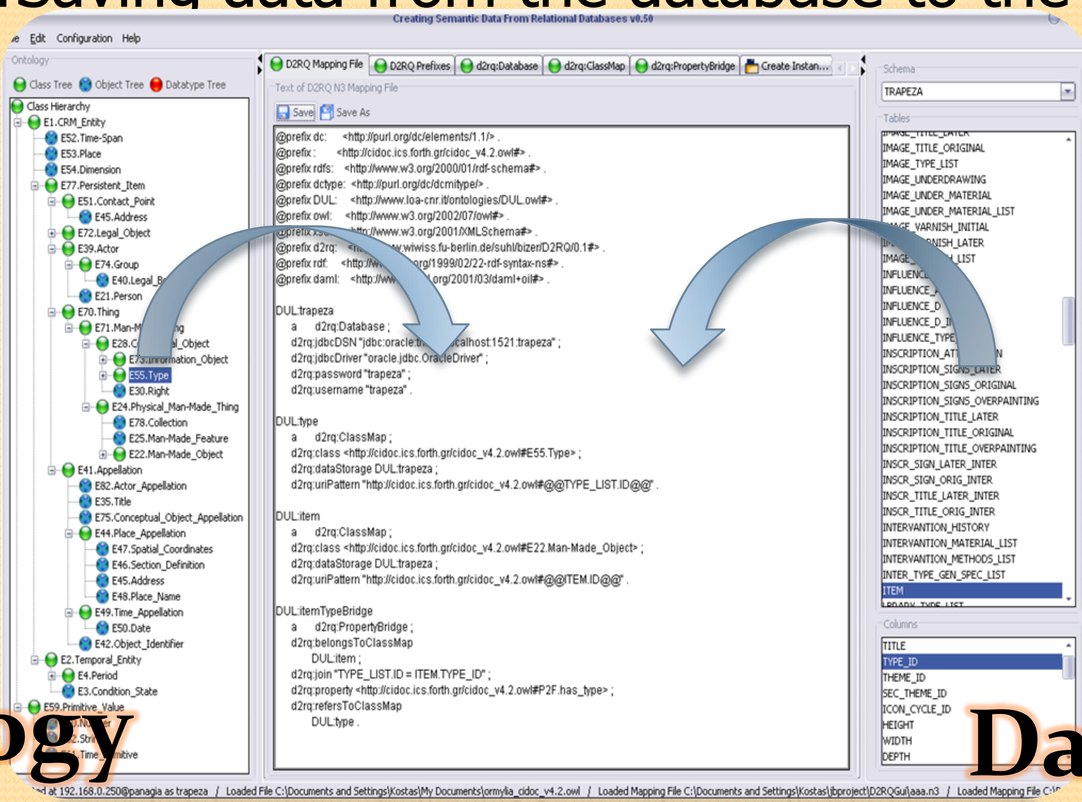
- ~8.500 Documented items
- ~25.000 Multispectral High Resolution Images
- ~10.000 Spectra
- ~6.000 Color Measures



Storage supporting the evaluation and the correlation of the information

Semantics

- Creating mapping files
- Saving data from the database to the ontologies

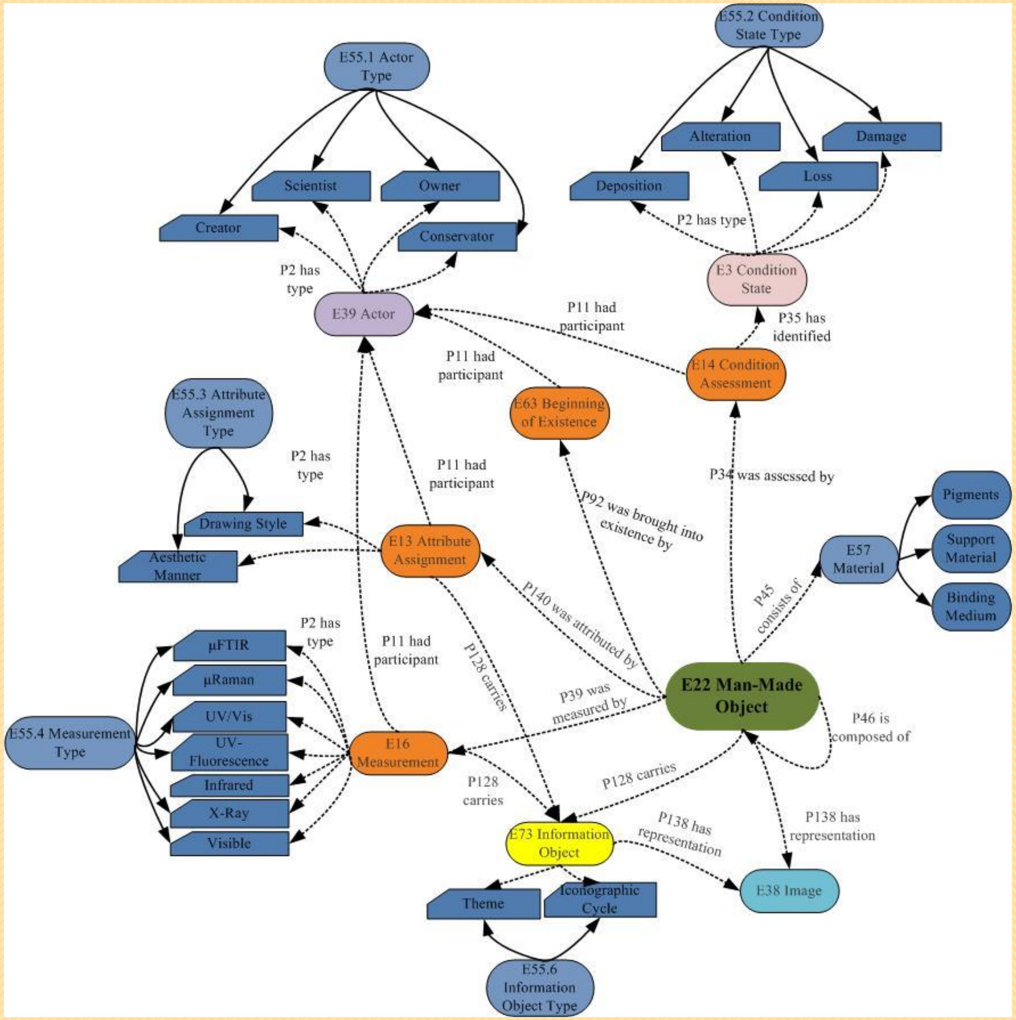


Ontology **Database**

Part of System «EIKONOMIA» – developed in the frame of project 05 ΑΚΜΩΝ 83 and «ΕΙΚΟΝΟΓΝΩΣΙΑ»

Semantics

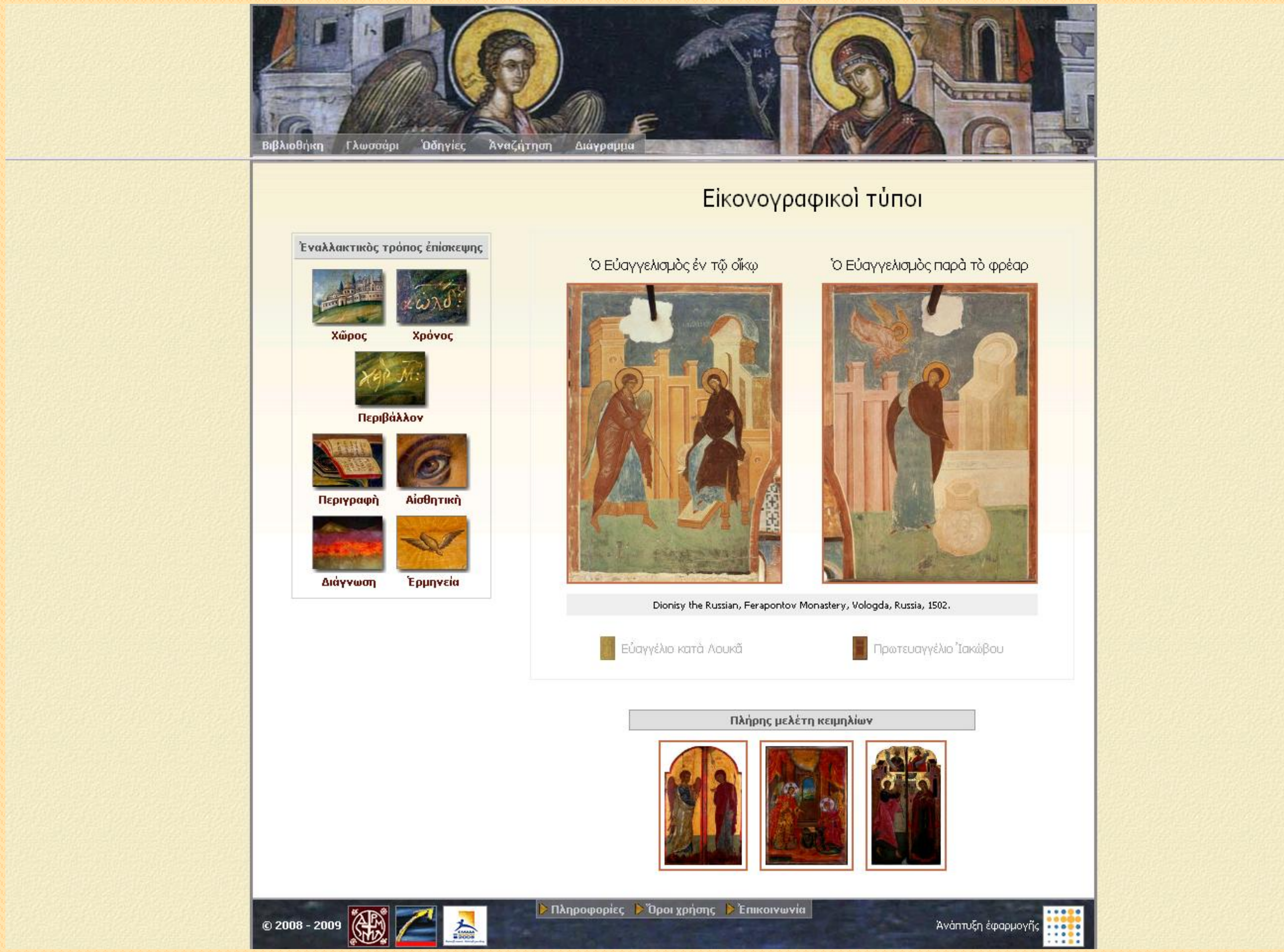
- Creating mapping files
- Saving data from the database to the ontologies



Part of System «ΕΙΚΟΝΟΜΙΑ» – developed in the frame of project 05 ΑΚΜΩΝ 83 and «ΕΙΚΟΝΟΓΝΩΣΙΑ»

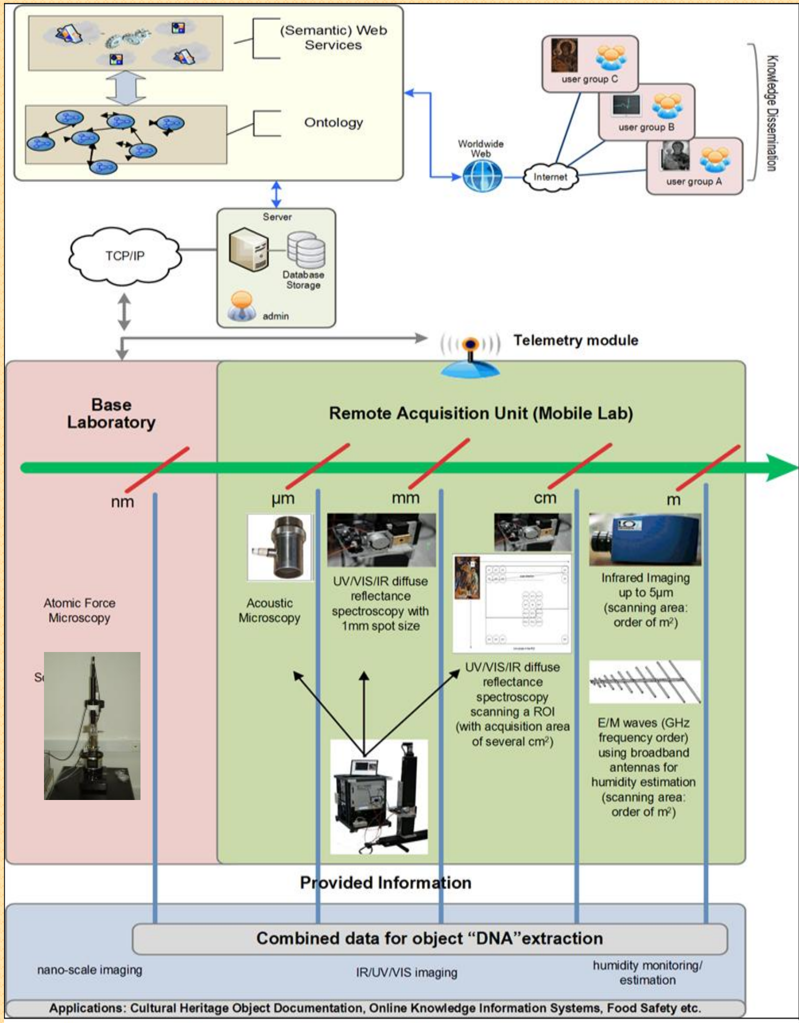
Semantics

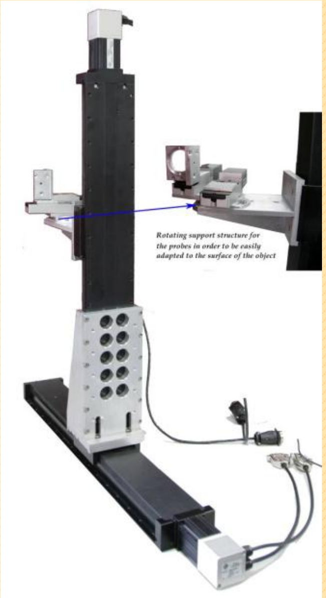
- Creating mapping files
- Saving data from the database to the ontologies
- … and present them to the WWW

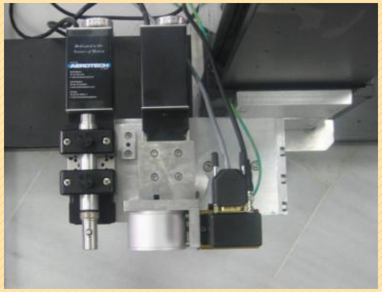


Resolution, Fidelity, Micro and Macro Information, …

- The resolution of the information can vary from macro (meters-centimeters scale) to micro (micrometers to nanometers) scale. In this point we reach the technological and the practical frontiers were the discussion must be thoroughly done trying to find a compromise between fidelity, reproducibility of measurements, portability of the infrastructure and non destructiveness…

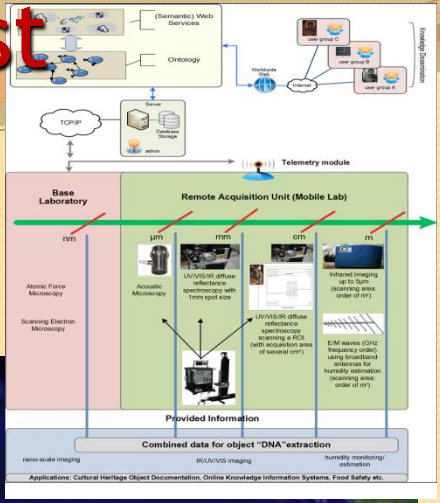




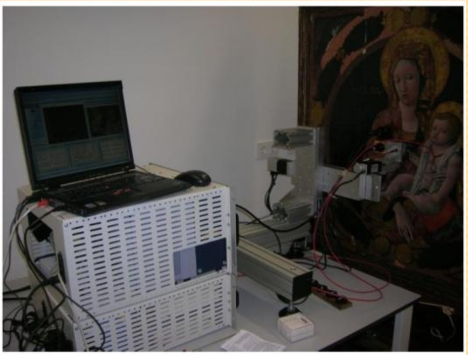


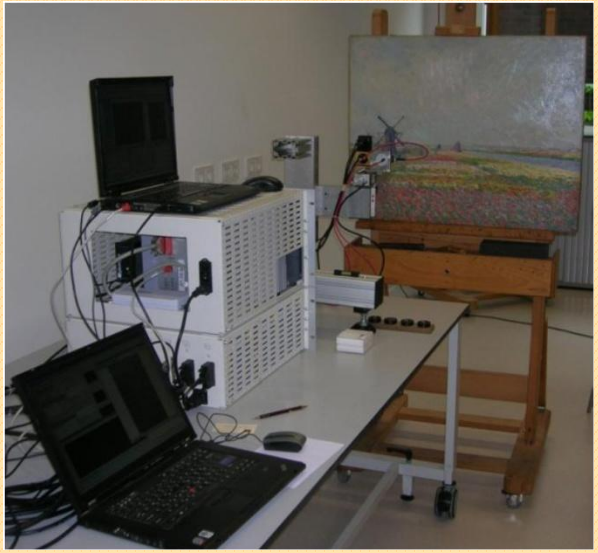
Step resolution of the XYZ stages which are used for scanning the ROIs of the objects is of 1μm

The installed infrastructure in East Mediteranean basin



Application on site and in situ to objects





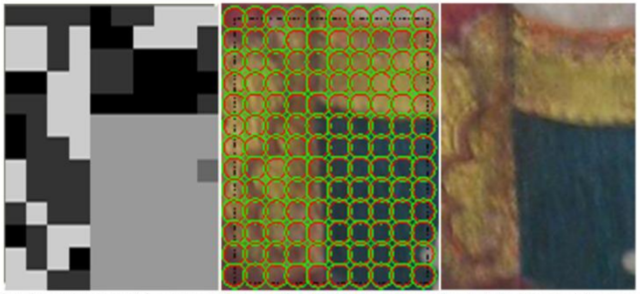


Figure 3: Clustering of the materials on the surface as well as in the paint layers of the painting in a specific scanned Region of Interest

Figure 4: Clustering of the materials on the surface as well as in the paint layers of the painting in a specific scanned Region of Interest from the underlayers

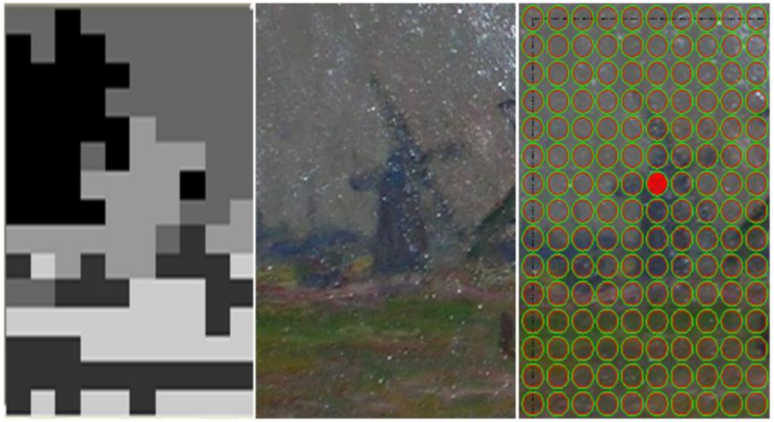
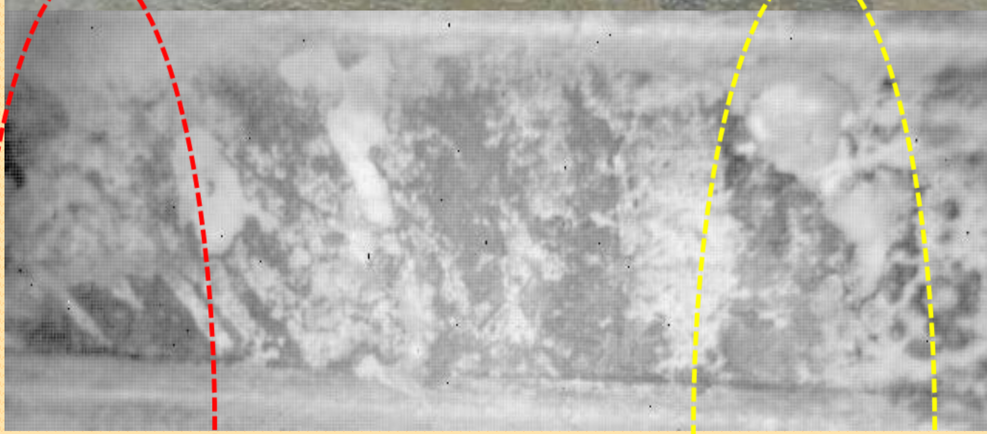
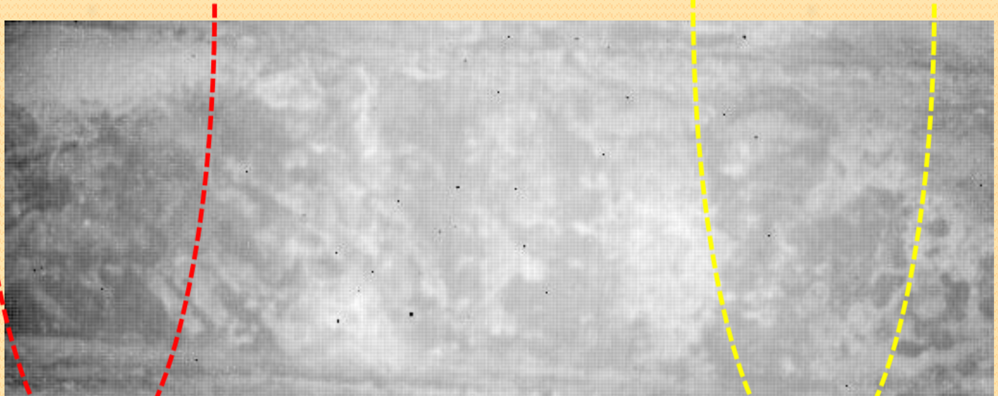


Figure 3: Clustering of the materials on the surface as well as in the paint layers of the painting in a specific scanned Region of Interest

Application on site and in situ to Monuments

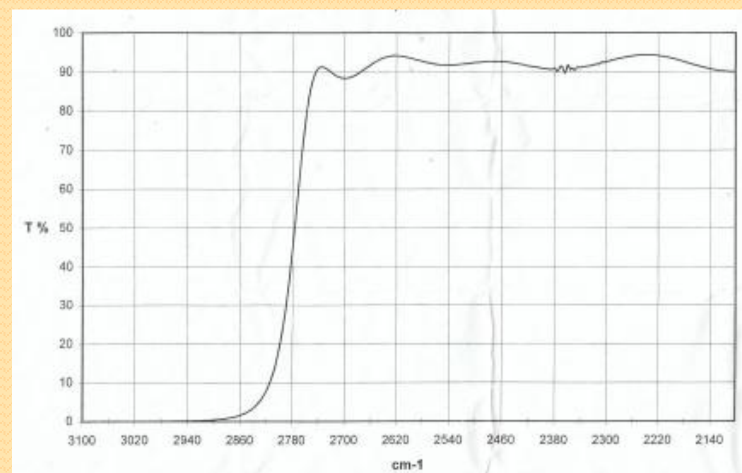
In collaboration with the Erechtheion restoration team





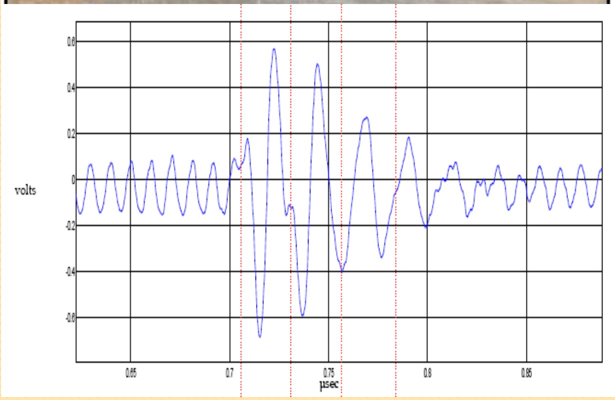
1800nm

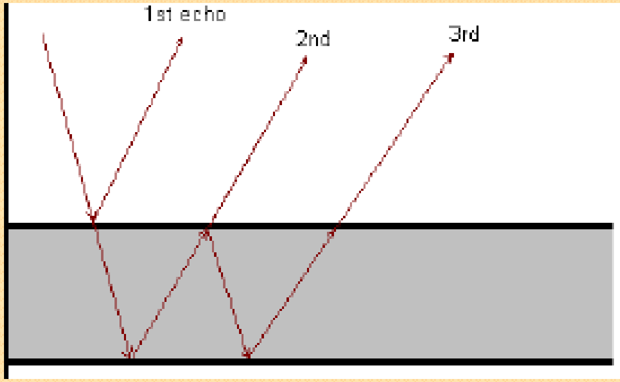
3597nm < λ

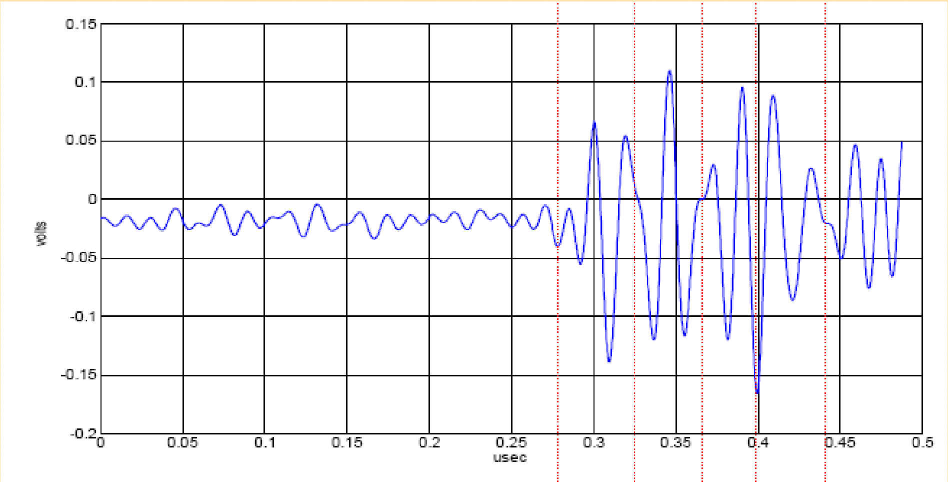


Application on site and in situ to Monuments

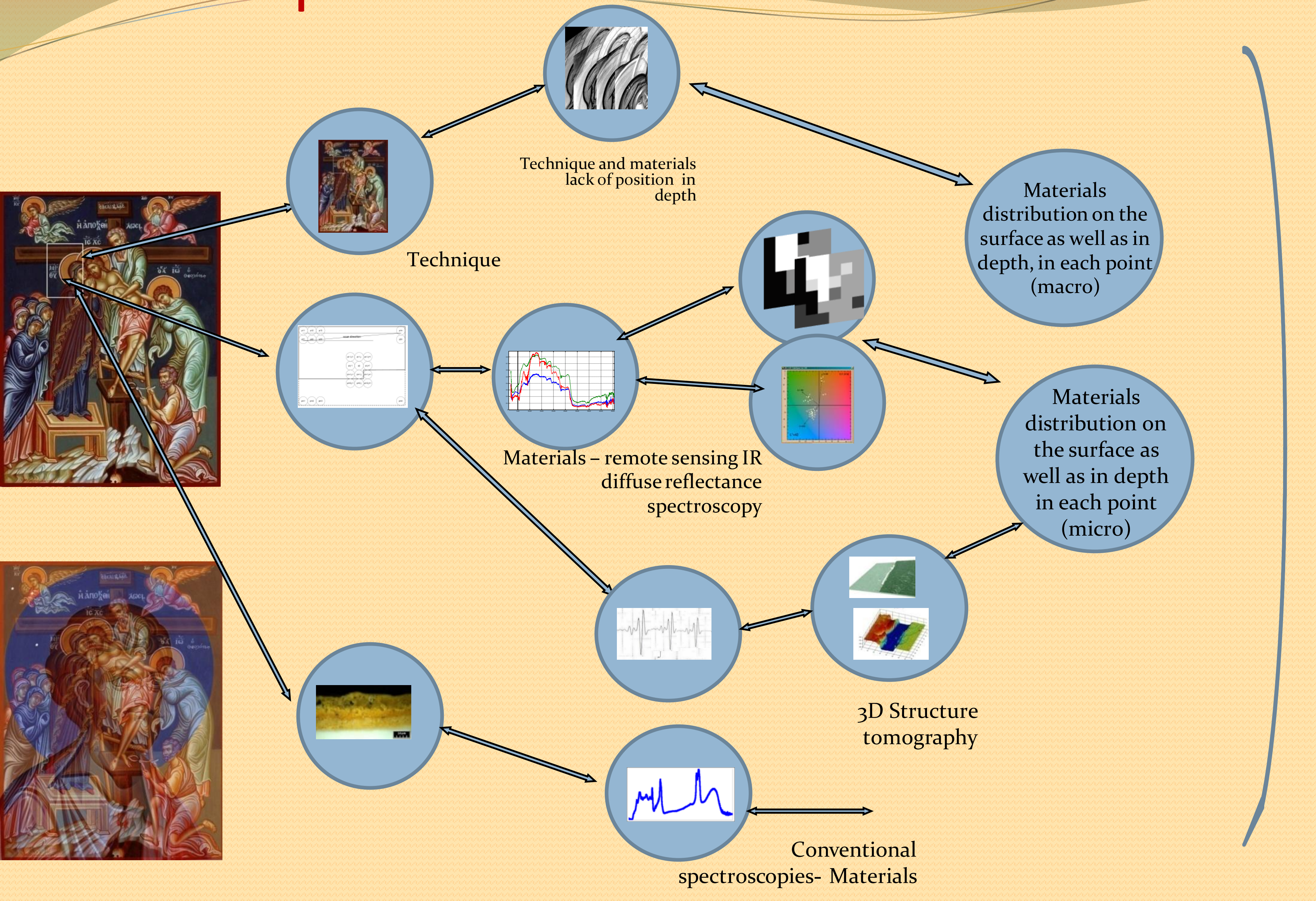
In collaboration with the Erechtheion restoration team





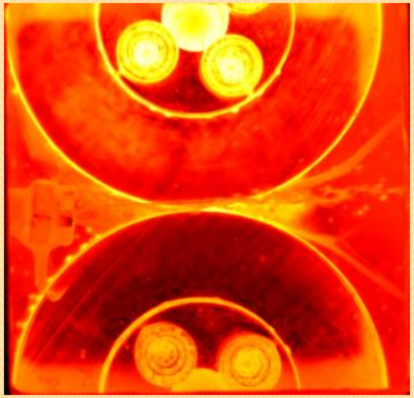


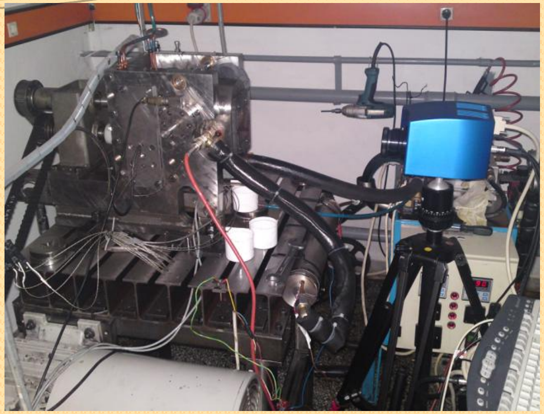
The concept- Conclusion



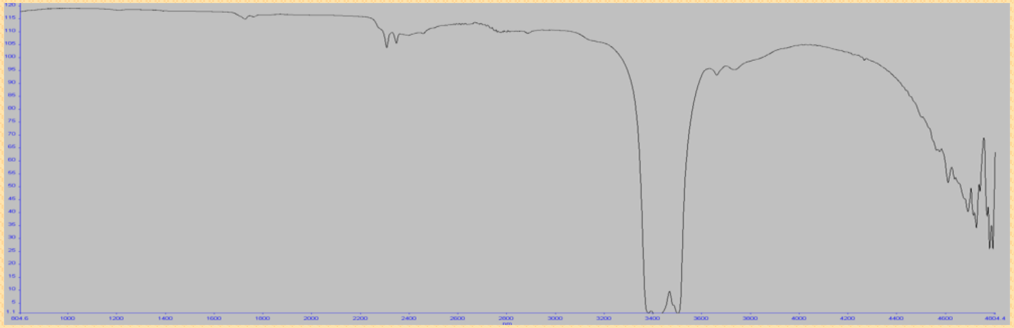
Conclusion - forthcoming work on NDT and quality check control in other fields

Real time imaging of the thermal field of the on the gears and roller bearings are presented (in collaboration with the Department of Mechanical Engineering, laboratory of Machine Elements and Machine Design of AUTh)

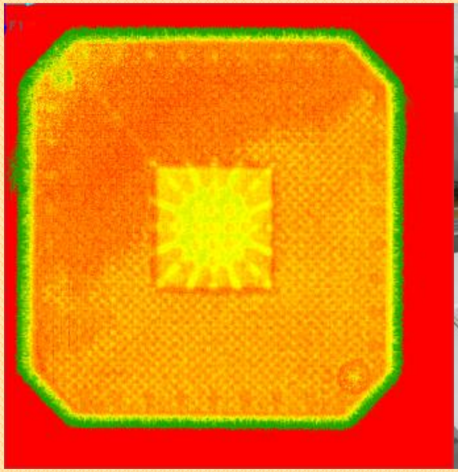


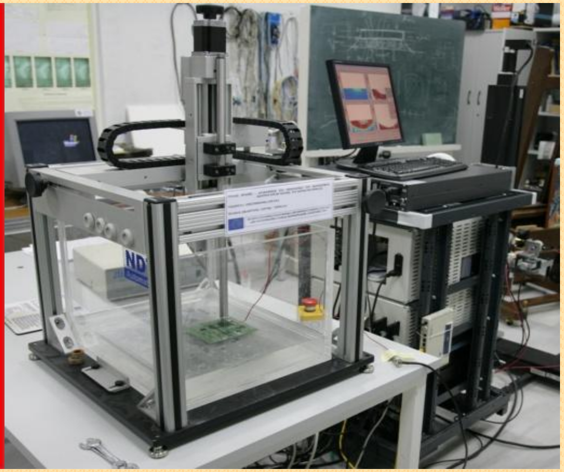


IR transmittance spectra of the oil used for the lubrication during the measurement



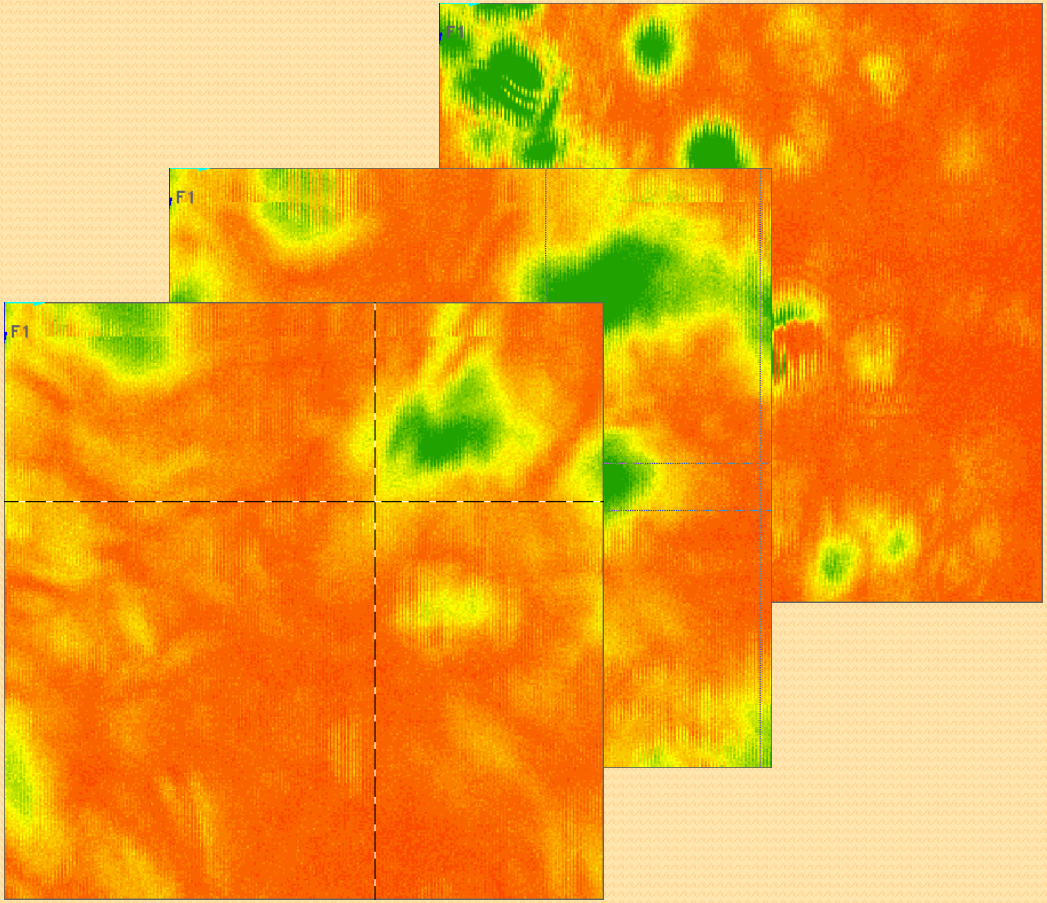
Evaluation of the underfilling material application to BGA arrays of ICs (110-175 MHz)





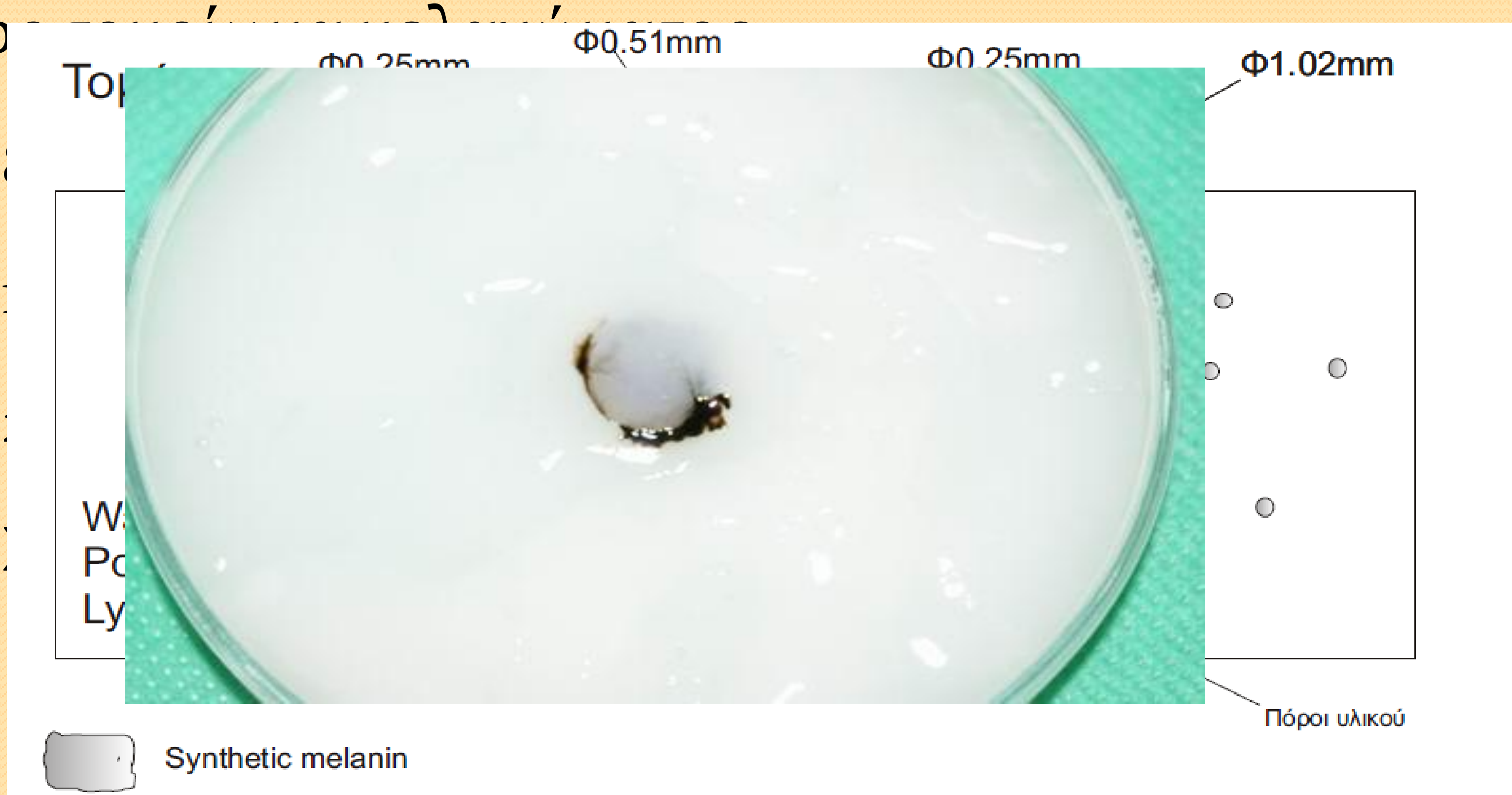
Conclusion - forthcoming work besides Cultural Heritage sector applications

Tomography of scaffolds for tissue engineering – artificiail bones using acoustic microscopy (110 MHz), in collaboration with chemical engineering department of of AUTh)

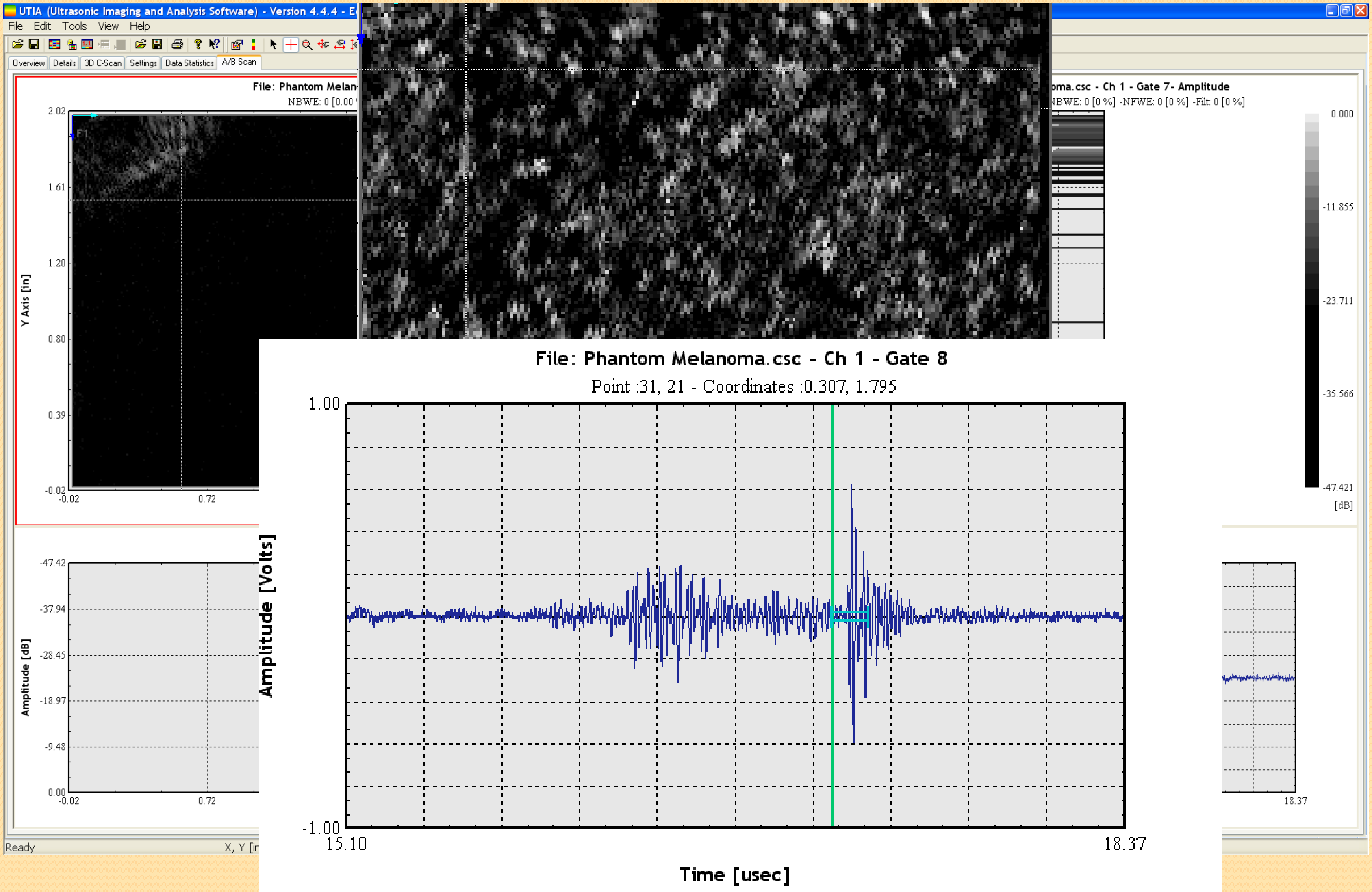


Phantom of Melanoma

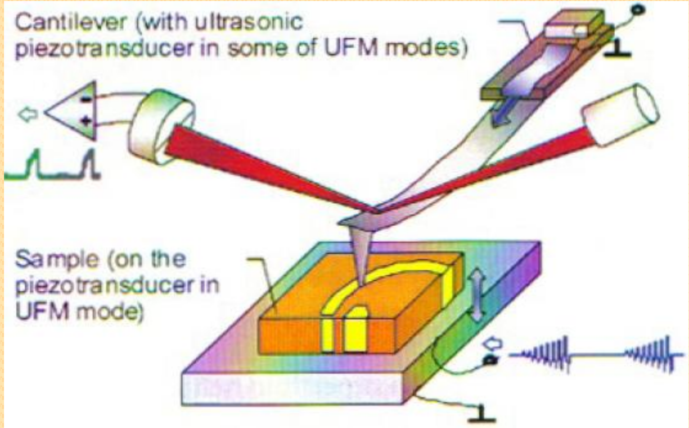
- Πρ

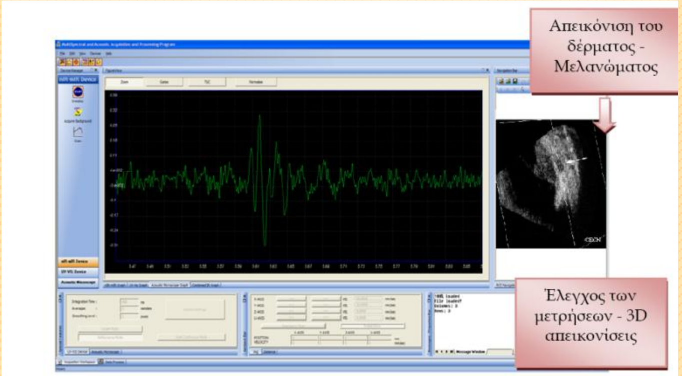


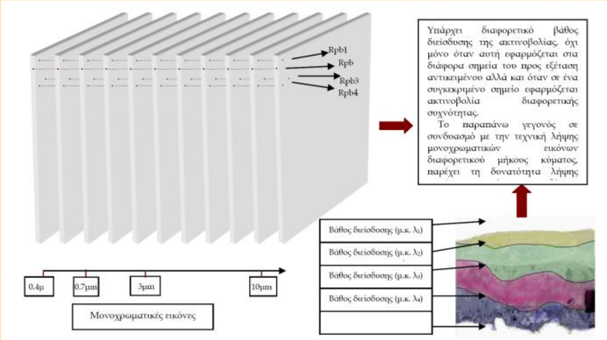
Scanning of the first phantoms using acoustic microscopy next step is the combination with the qualitative information that will be provided applying IR difuse reflectance micro spectroscopy

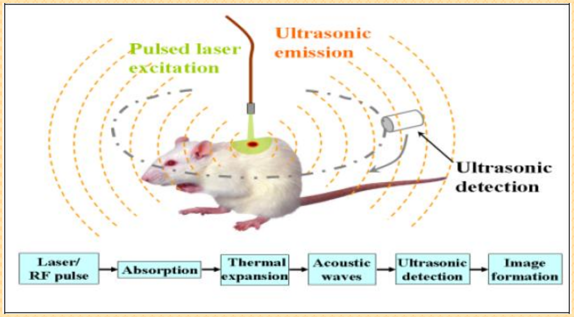


Conclusion - Forthcoming work – Ultrasonic Force Microscopy – Combination of the Electromagnetic excitation with the ultrasonic emission - Photoacoustic phenomena









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4 PhDs
Several diploma thesis

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