Scan4Reco

"Multimodal Scanning of Cultural Heritage Assets for their multi-layered digitization and preventive conservation via spatiotemporal 4D Reconstruction and 3D Printing"

Scan4Reco, Horizon 2020 Project

Project Overview

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European Commission

Horizon 2020
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Summary

- **Grant Agreement No.:** 665091
- **Project acronym:** Scan4Reco
- **Project title:** Multimodal Scanning of Cultural Heritage Assets for their multi-layered digitization and preventive conservation via spatiotemporal 4D Reconstruction and 3D Printing
- **Start date:** 01/10/2015
- **Duration:** 36 Months - **Currently @ M13**

- **Project website:** www.scan4Reco.eu

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Consortium

Centre for Research & Technology - Hellas /Information Technologies Institute (Coordinator, Greece)

"ORMYLIA" FOUNDATION, ART DIAGNOSTIC CENTRE (Quality Manager, Greece)

Fraunhofer Institute for Computer Graphics Research IGD (Germany)

University of Verona (Italy)

Opificio delle Pietre Dure (Italy)

Center for Research, Development, and Advanced Studies in Sardinia (Italy)

BW TEK Inc. (Germany)

Avasha AG. (Switzerland)

Research for Science, Art and Technology (RFSAT) Ltd (United Kingdom)

Rationale

With respect to Cultural Heritage documentation & preservation, the following holds:

- **enormous European Cultural Heritage** (CH) including a vast and rich variety of cultural items
- different **materials** with different **ageing patterns**
- different **restoration procedures**
- **multi-factorial** reasons for the CH **deterioration**
- lack of detailed & efficiently collectable **documentation**

- **enriched 3D representations** (printed or digital) is valuable for conservators
- limited **accessibility to public**

The *Scan4Reco* Vision

"Truth is like a sculpture - one perspective is never enough for true understanding"
F. Nietzsche

Scan4Reco will offer a **multi-angle** (in spatio-temporally terms) **view** of the objects

Scan4Reco will facilitate the **preservation**, **conservation, curation**, **restoration** & the **documentation** via **automatic digitization** of a wide variety of **cultural heritage assets** even **in situ**, using:

- **accurate 3D reconstruction** models,
- **multispectral scanning** & digitization,
- **material exploration**,
- **identification and modelling**,
- **tactile multilayered surrogates** for both **scientific and commercial usage.**
- demonstration in **virtual museum**

Objectives

- Development of a novel, portable, integrated, modular **solution** for customized, cost-effective, automatic **digitization** and **analysis** of **Cultural Heritage Objects (CHOs)**, even in situ, using:
  - ✓ **Multi-sensorial 3D scanning** facilitated by a **mechanical arm** to collect multi-spectra data used for the application of **hierarchical approach** for **3D reconstruction** of CHOs that will enable **multi-layered rendering** for analysis and **3D printing**
  - ✓ Creation of high precision **digital surrogates** of CHOs to provide details about **surface**, **volumetric structure**, **material composition**, **shape/structure of underlying materials** and to render them via **visualization techniques** or **via transparent multi-material 3D printing**
  - ✓ **Material Analyses** to understand heterogeneity of CHO, to identify classes of materials, to understand degradation mechanisms over time, to create **ageing models** per material
  - ✓ **Spatiotemporal Simulation** of CHOs to render degradation effects, predict and recreate CHOs' future appearance and automatically restore them
  - ✓ A **Decision Support System** to suggest over appropriate **conservation methods** for the indicated by Scan4Reco spots/segments of CHOs that are in eminent conservation need
  - ✓ A **Virtual Museum** to enhance accessibility of the digitized cultural objects to scientific community, field experts, general public

Use Cases & Pilots

- **Two classes** of cultural heritage objects, i.e. **paintings** & **metallic objects** will be used as validation pilots.
- Use cases:

✓ **Environmental conditions & metadata definition**

- Environmental conditions of artwork degradation and the corresponding type of restoration intervention will be defined and studied.

✓ **Cultural Object Scanning**

- A selected artwork will be digitally acquired to generate (a) a global coarse-resolution 3D representation of the color and geometry of the artwork and (b) local physical and chemical measurements of small, flat areas on the artwork surface/subsurface.

✓ **Spatiotemporal Simulation**

- Virtually simulating the evolution of artwork condition over time, in order to make reliable prediction on the object behaviour and the effect of the restoration treatments.

✓ **Analysis & Guidelines generation**

- It will provide curators and restorers with a rendering-based help to take the right operational strategy.

✓ **3D Visualization, Interaction & 3D Printing**

- Using visualization tools, both virtual and physical, will allow for a real-time, easy interaction between the end-users, scholars, curators and general public, and the cultural heritage assets.

Envisioned Use-Cases (1/2)

Paintings

- **Where?**
  …in the conservation laboratories of **OF-ADC** located in Chalkidiki, Greece.

- **Who?**
  …Conservation scientists and conservators

- **What?**
  …art objects that are received in the Lab for documentation services from the real market
  …available real painted art-objects from Mount Athos

- **Why?**
  …scanning with the various modalities
  …reconstruct the tomographic information using the 3D visualization models.
  …stratigraphy determination (acoustic microscopy)
  …elements detection in the layers (xRF)
  …evaluation of the chemical changes in the materials (FTIR and Raman spectroscopies)
  …3D reconstruction & printing to see if the information provided is useful for the conservation treatment of the art object. From this procedure, the following system components will be utilized and evaluated in the real case object accordingly

Envisioned Use-Cases (2/2)

Metallic and other 3D objects

- **Where?**

  …museums of the "**Soprintendenza**" of Venice and of Verona and by the **OPD** national restoration facility.

- **Who?**

  …professional conservation scientists of the museums and institutes

- **What?**

  …metallic and other 3D objects will be carried out on genuine artworks (e.g. bronze sculptures and reliefs, silver alloy jewellery, wax sculptures, glasses, etc.)

- **Why?**

  … scanning of the surface with the multi-modal and multi-sensor platform and reconstruct the information at multiple scales using the 3D visualization models.

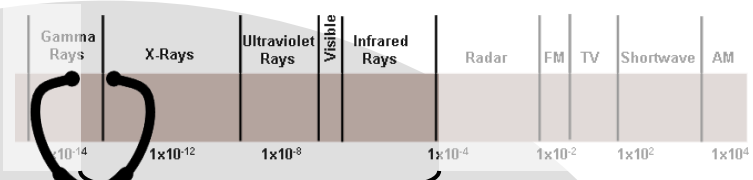
  …object reconstruction (commercial depth sensors/cameras)

  …quantitative representation of the surface texture & roughness at micrometric level (microprofilometry).

  …model of materials reflectance and geometric information/details (multispectral RTI)

  … reference palette & artwork inspection, conservation status, ageing and proposed treatment (visualization & 3D printing of the reconstructed object, material morphology and stratigraphy)

The *Scan4Reco* Concept



Artificial ageing

Ageing models

UltraSonic

X-Rays

Ultraviolet

Infrared

Laser

Multimodal & Multisensorial Fusion

Rendering & Simulation

Knowledge database

Use Cases

Depth Infiltration

Multimodal & SpatioTemporal Inferative Reconstruction

Timeline

Virtual Museum

www

Interactive - Visual Analytics

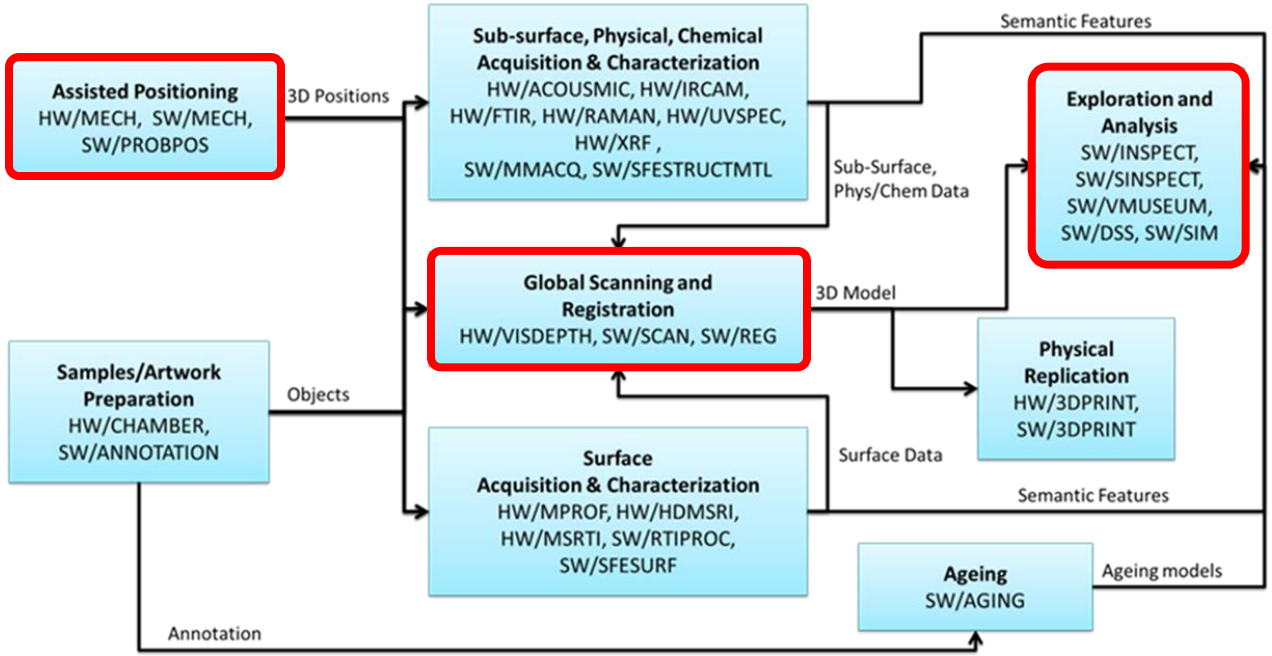
User Feedback

High-level Architecture Structure

Lab environment

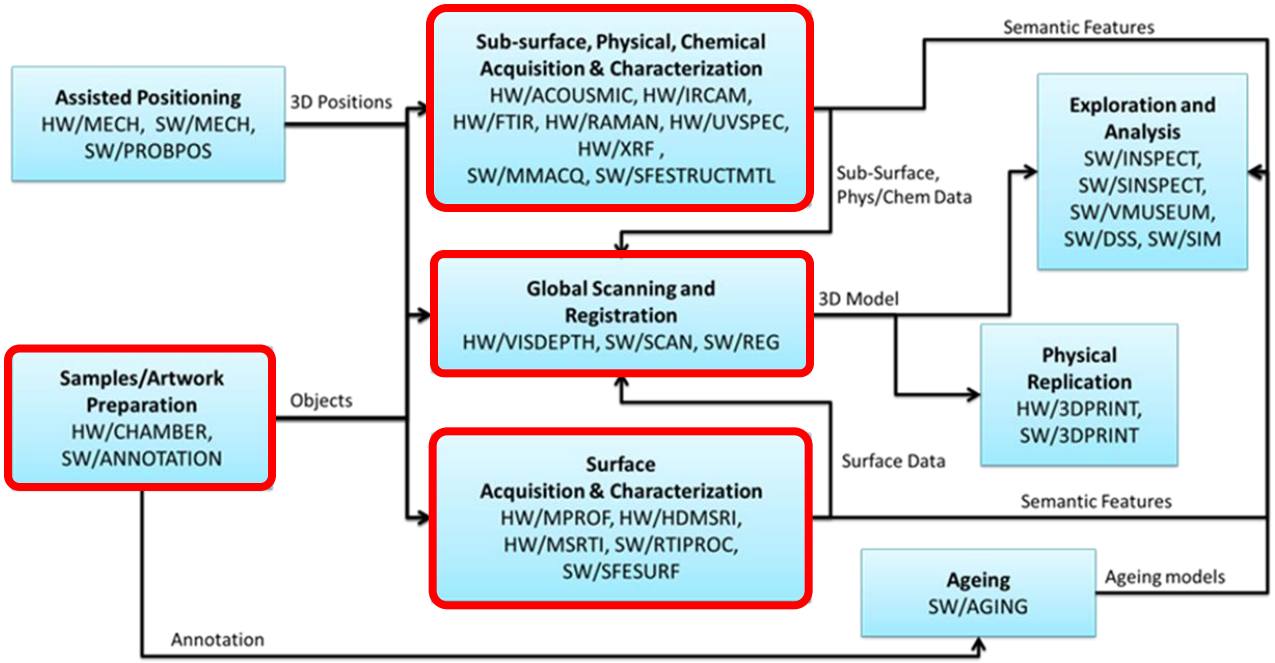
Hardware (HW) and **Software (SW)** components of Scan4Reco have been categorized into **8 sub-systems** based on functionalities and main data flowing between them

- **Assisted Positioning**
- **Samples/Artwork Preparation**
- **Sub-surface, Physical, Chemical Acquisition & Characterization**
- **Global Scanning and Registration**
- **Surface Acquisition & Characterization**
- **Exploration & Analysis**
- **Physical model Replication**
- **Ageing**



High-level Architecture Structure
In Situ

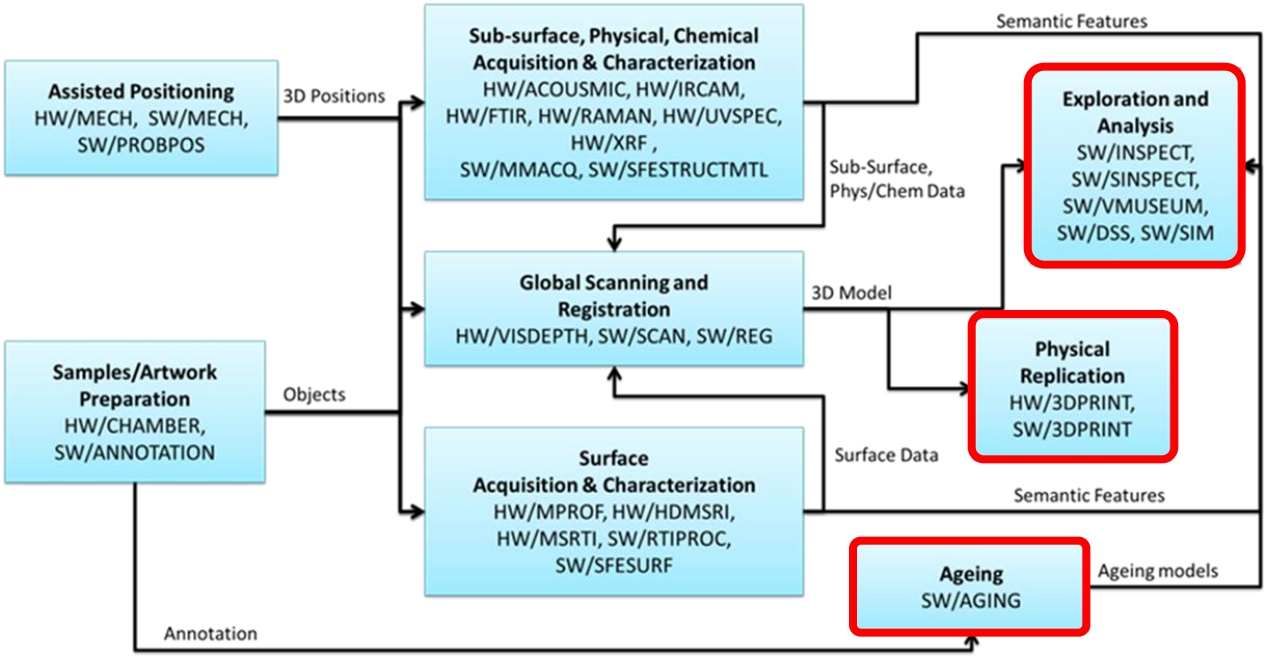
- Assisted Positioning
- Samples/Artwork Preparation
- Sub-surface, Physical, Chemical Acquisition & Characterization
- Global Scanning and Registration
- Surface Acquisition & Characterization
- Exploration & Analysis
- Physical model Replication
- Ageing



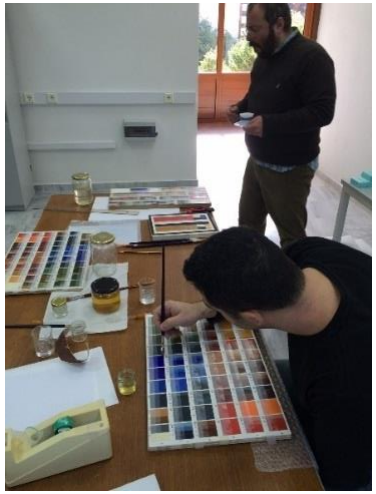
High-level Architecture Structure

Off-Site

- Assisted Positioning
- Samples/Artwork Preparation
- Sub-surface, Physical, Chemical Acquisition & Characterization
- Global Scanning and Registration
- Surface Acquisition & Characterization
- Exploration & Analysis
- Physical Replication
- Ageing



Overview of pigments/samples with varnish



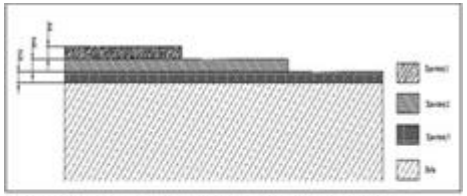


Figure 18: Design of the panel with combination of successive layers of pure pigments or of mixtures of them in each sub layer.

Figure 19: Design of the 3d structure of the panel with combination of successive layers of pure pigments or of mixtures of them in each sub layer.

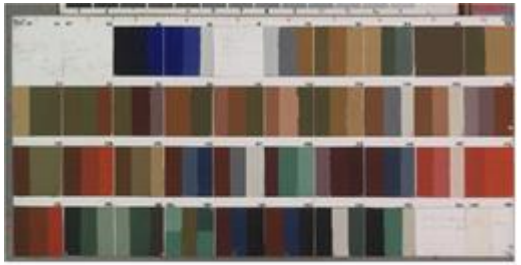


Figure 20: Combination of successive layers of pure pigments or of mixtures of them in each sub layer.

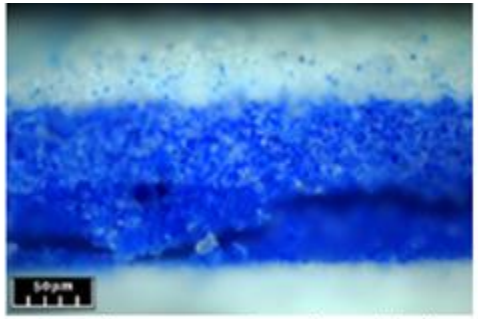


Figure 21: Cross section of a reference samples of combination of successive layers of pure pigments or of mixtures of them in each sub layer displayed in Figure 20

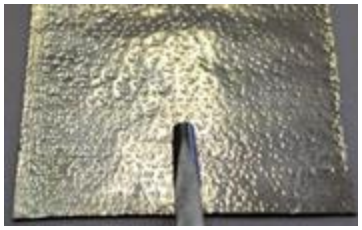
Overview of metallic reference samples

- **COATED SILVER SAMPLES**

Silver SET1: 16 samples

Silver SET2: 16 samples

Two not treated samples (one smooth and one chased)



- **COATED BRONZE SAMPLES**

Bronze SET1: 9 samples

Bronze SET2: 9 samples

One not treated sample

- **BRONZE SAMPLES WITH PATINA**

Patina SET1: 16 samples

Not treated strips in between areas with patina

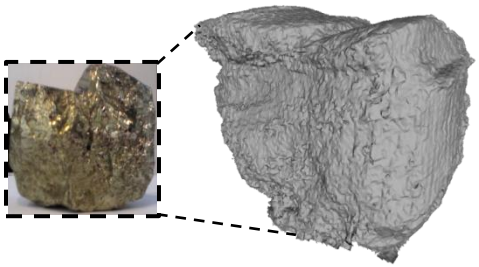
Data acquisition process

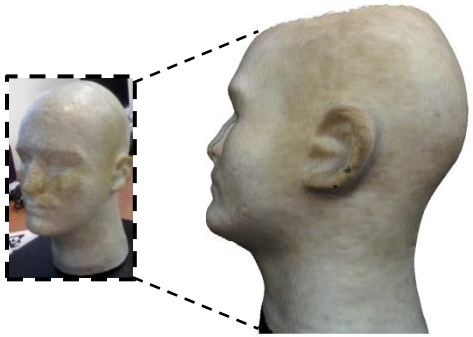
3 layers

- **3D** (Global) Scanning & **Registration**
  - Generate a global 3D coarse-resolution geometric and chromatic representation
    - Depth camera setup for capturing color and depth information (quick)
    - High Resolution colour sensor (high resolution)
  - Perform registration of the local, punctual measurements performed by other sub-systems onto the global 3D resolution geometrical proxy
- **Surface** Acquisition & Characterization of materials through:
  - Optical micro-profilometer
  - High-Density Multispectral Reflectance Imager
  - Multispectral Reflectance Transformation Imager
- Perform **sub-surface** acquisition & characterization (i.e. physical & chemical):
  - Acoustic microscope
  - Infrared camera
  - Fourier Transform Infrared spectrometer
  - Raman spectrometer
  - UltraViolet/Visible spectrophotometer
  - X-ray Fluorescence spectrometer

3D Scanning

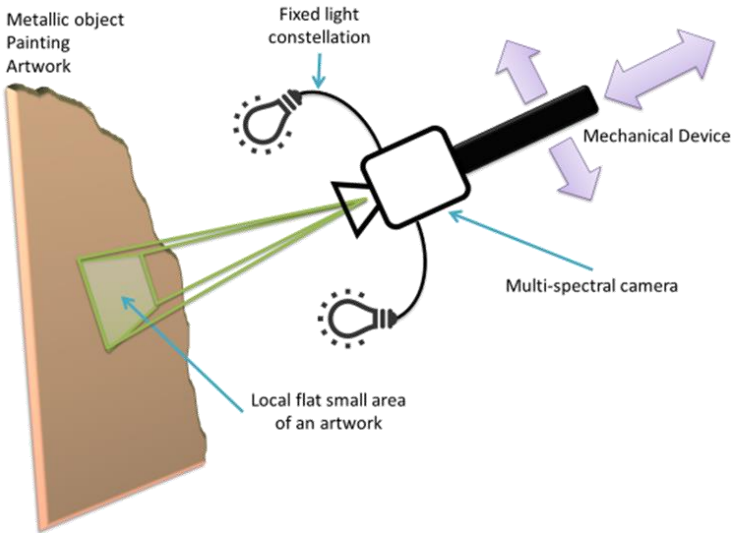
- Create **3D models** of cultural objects for dynamic and precise understanding of the object shapes and temporal changes in time
- Form the **surface & volumetric** analysis in 3D models using 2D and 3D information:
  - deformable modelling techniques to describe a dynamic volumetric behaviour
  - texture and surface techniques to model the surface of the objects.
- Incorporating **material properties** into 3D models, surface and texture properties, to be able to simulate dynamic physical behaviour
- Ability to **represent physical characteristics** of an object, such as a material, elastic and plastic properties, etc.
- Develop **algorithms** able to determine temporal changes to object shapes with indication of **past & possible future** evolution

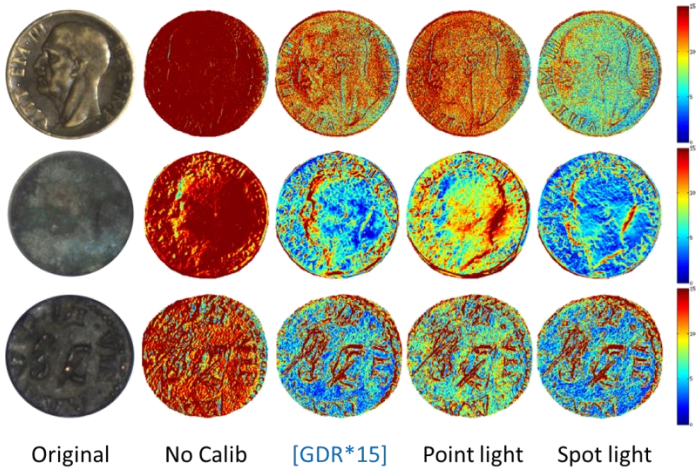


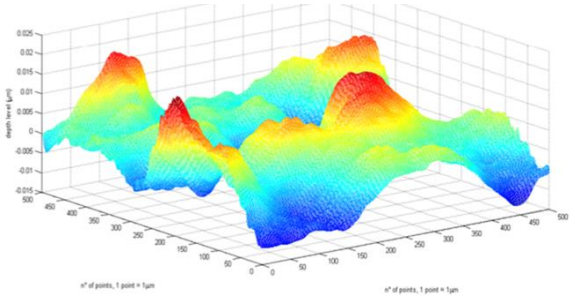


Surface Acquisition & Characterization

- Goal
  - Acquisition and characterization of material behavior in the outmost layer of an object surface
  - Representation of materials through semantic features computed from signals such as micro distortions (bumps, normal maps), roughness, 3D microstructure, level of glossiness, scratches, etc.
- Approach
  - Micro 3D capture by using **optical micro-profilometer**
  - Appearance capture from **multi-spectral Reflectance Transformation Imaging (MS-RTI)**
  - Robust processing pipeline to produce an integrated and manageable per-point representation of the reflectance data
  - Extraction of semantic features from surface measurements performed with micro-profilometer and RTI software







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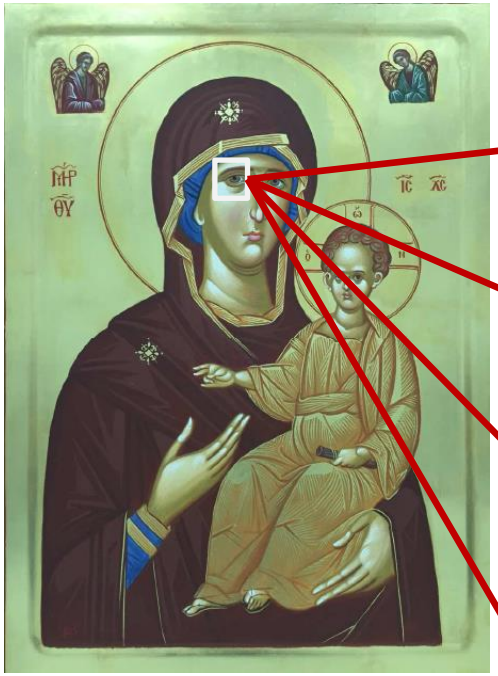
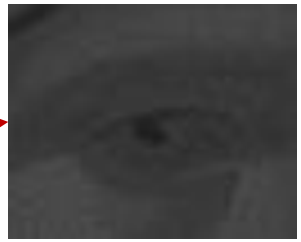
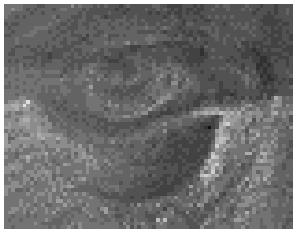
Sub-surface acquisition & Characterization

…measuring underlying layers

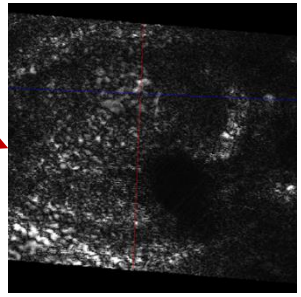




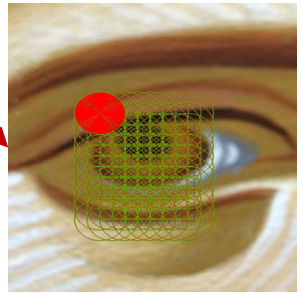
IR imaging 1-5µm



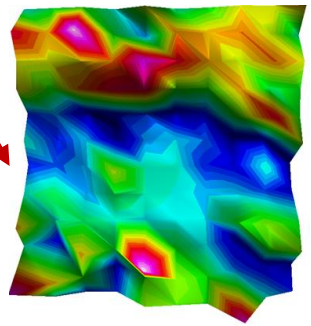
Ultrasound & IR imaging



Ultrasonic µTomography



UV-VIS Spectroscopy



IR Spectroscopy

Information provided

Surface topography, colour

Underdrawings,

Thickness measurements of the layers

Material identification

Initial designs, Underdrawings

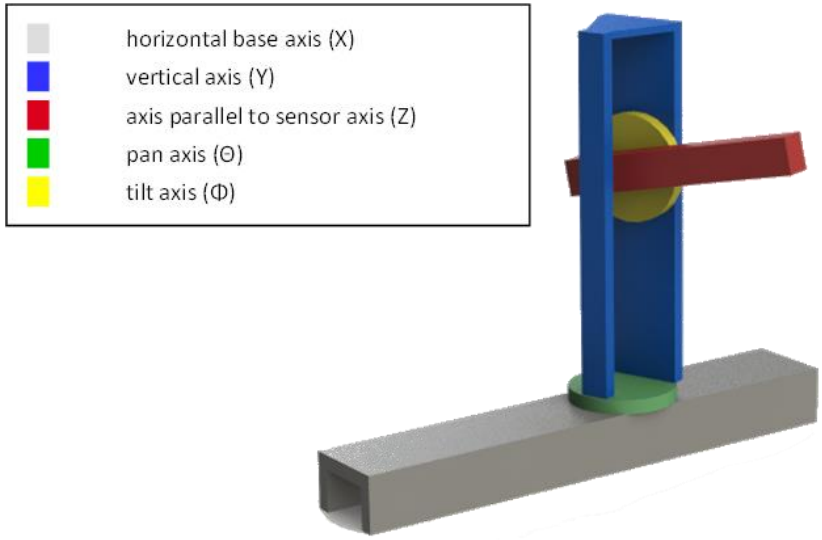
Roughness,

elastic properties of the materials

Assisted Positioning

Mechanical Arm

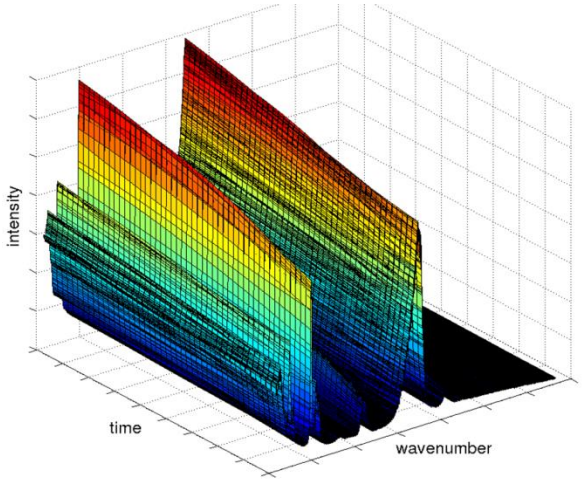
- Assist the artwork's acquisition
- Is a **multi-axis** positioning system
- Allow to **mount sensor probes** and to **move them to positions** relative to the cultural heritage object under observation



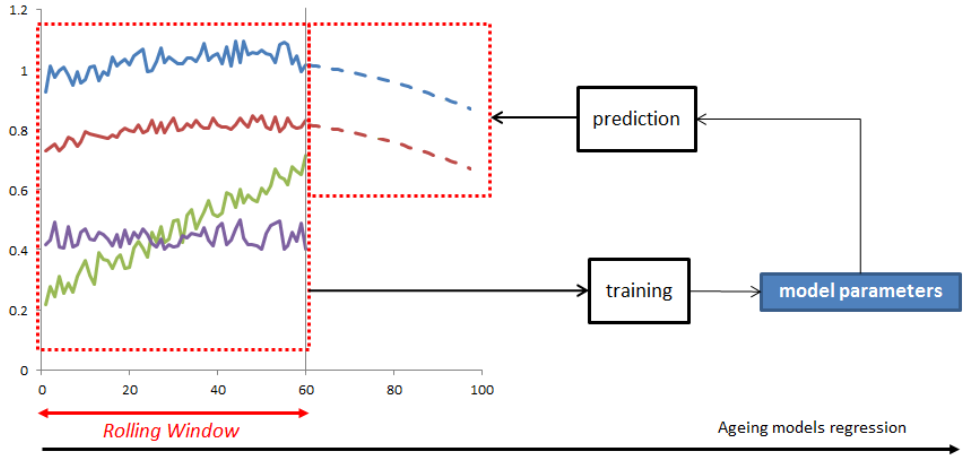
Schematic diagram of the designing coarse positioning system

Ageing Models

measurements & prediction



- Spectra from various sensors at different time instants
- Estimate spectrum values at specific time and wavenumber (t, n)
- Estimate ageing model parameters through training or regression, using the historical data.
- After the model parameters are learned, they can be used for prediction.



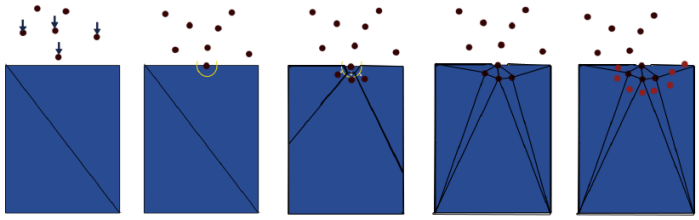
- Can use interpolation techniques e.g. curve/surface fitting using polynomial regression
  $\hat{a} = (X^T X)^{-1} X^T y$
- If needed other algorithms are applicable (e.g. segmented regression, neural networks etc.)

Simulation & Dynamic Reconstruction

- **Visual Simulation** of material aging and weathering
- **Deterioration Modelling** of material's **appearance** & **geometry**

Color change (appearance deterioration) of a metallic coin by weathering

Cracking and peeling (geometry deterioration) of wall paint by weathering



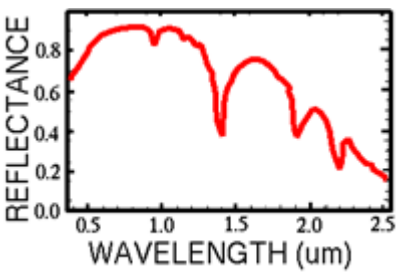
u-ton based approach

…from spectral data to visualization

Problem formulation: Visual interpretation of the multi-spectral data & the aging models to the material-aging-related parameters for simulation.

Required information/parameters:

- ✓ the **effects of aging** (e.g. colour change, cracks generation, etc.),
- ✓ the **addition/subtraction of blemish**,
- ✓ the **type of blemish**,
- ✓ the **material properties** that changed and led to appearance/structure changes
- ✓ etc.



Black box

Parameters of the material aging model

Physical Replication

- Creation of a **multi-material replica** of the 3D model (OFFSITE) with the attached multi-modal signals
- Illustrative **3D printing procedures** might be employed to tangibly represent the **volumetric structure of the materials**

Stratasys Objet 500 Connex3 printer employs 3 build materials

Stratasys J750 printer employs 6 build materials

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www.scan4reco.com

Horizon'2020-Scan4reco Project

- http://twitter.com/scan4reco
- http://www.facebook.com/groups/982430741820987/
- http://www.linkedin.com/groups/8428972

Public Deliverables

available online

Del. No	Deliverable name	WP No.	Short name of lead partic.	Type	Dissem. level	Delivery date
D8.1	Scan4Reco Web Site	WP8	CERTH	DEM	PU	M1
D1.3	Ethical Issues Manual	WP1	OF-ADC	R	PU	M5
D1.2	Data Management Plan	WP1	OF-ADC	R	PU	M6
D2.3	Scientific end-user and public requirements	WP2	OPD	R	PU	M6
D8.2	Communication plan	WP8	AVASHA	R	PU	M6
D2.2	System Architecture definition	WP2	CRS4	R	PU/CO	M9
D3.1	Material related Booklet	WP3	OF-ADC	R	PU	M10
D3.2	A guide for multi-material palette preparation	WP3	OF-ADC	R	PU	M10
D2.1	Technology exploration report	WP2	RFSAT	R	PU	M12
D2.4	Initial Report on System Specification	WP2	OF-ADC	R	PU/CO	M12
D3.3	Procedures and application of artificial ageing	WP3	OPD	R	PU	M12

Publications (1/4)

1. **G. Karagiannis**, "*A 3D spectroscopic mapping tomography applied to art objects diagnosis*", presented at the International conference on Innovation in Art Research and Technology (InART), Ghent Belgium, 22-25th March 2016, published in a book of abstracts, pages 93-94 (FREE Access).
2. **G. Karagiannis, G. Apostolidis**, "*Investigation of stratigraphic mapping in paintings using micro-Raman spectroscopy*", presented at SPIE Photonics Europe 2016, SQUARE Brussels Meeting Centre, Brussels, Belgium 4-7th April 2016, published at Proceedings of SPIE 9899, Optical Sensing and Detection IV, 98990U (29 April 2016); DOI: 10.1117/12.2225211 (SPIE copyrighted).
3. **G. Karagiannis**, "*High resolution spectroscopic mapping imaging applied in situ to multilayer structures for stratigraphic identification of painted art objects*", SPIE Photonics Europe 2016, presented at SQUARE Brussels Meeting Centre, Brussels, Belgium, 4-7th April 2016, published at Proc. SPIE 9896, Optics, Photonics and Digital Technologies for Imaging Applications IV, 98961F (29 April 2016); DOI: 10.1117/12.2227943 (SPIE copyrighted).
4. **G. Karagiannis**, "*Spectroscopic mapping tomography*", presented at SPIE Photonics Europe 2016, SQUARE Brussels Meeting Centre, Brussels, Belgium 4-7th April 2016
5. **R. Pintus, E. Gobbetti, M. Callieri, M. Dellepiane**, "*Techniques for seamless color registration and mapping on dense 3D models*", In: N. Masini (Ed), "Sensing The Past", Springer, April 2016
6. **G. Karagiannis**, "*Non-destructive endoscopy of cultural heritage objects of various kinds and materials*", presented at the International Symposium on Archaeometry (ISA'2016), 15-21st of May 2016 Kalamata, Greece, to be published in the Routlege Open Access (OA) journal on "Science and Technology of Archaeological Research (STAR)" by Maney Publishing's, volume 2, Issue 2 (2016).
7. **Cagnini A., M. Galeotti, S. Porcinai and B. Salvadori**, "*TR-FTIR techniques to support the conservation of metal surfaces: application to Renaissance gilded artefacts*", presented at the IRUG12 Conference, Ormylia, 23-25th May 2016, published in "Book of Abstracts", page 15 (FREE Access).

Publications (2/4)

8. **Giatti A., M. Galeotti and G. Lanterna**, "*Non-invasive FTIR characterisation of varnishes of ancient brass scientific instruments belonging to the "Physic Cabinet" of the "Fondazione Scienza eTecnica" in Florence*", presented at the IRUG12 Conference, Ormylia, 23-25th May 2016, published in "Book of Abstracts", page 16 (FREE Access).
9. **Daffara C., G. Marchioro and E. Zendri**, "*Thermal quasi-reflectography (TQR), handheld Raman spectroscopy, and optical profilometry: multi-technique mapping of decay in wall paintings*", presented at the IRUG12 Conference, Ormylia, 23-25th May 2016, published in "Book of Abstracts", page 17-18 (FREE Access).
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13. **G. Karagiannis, C. Salpistis, F. D. Demosthenous**, "*Application of 3D spectroscopic mapping imaging using the mobile laboratory of ORMYLIA Foundation. The case of an icon of the Holy Archbishopric of Cyprus*", presented at the 2nd International Meeting for Conservation & Documentation of Ecclesiastical Artefacts-Halki (IMCDEA'2016) (Constantinople), 8-9th July 2016, to be published in the thematic issue of the ODYSSEUS Scientific Journal in October 2016.
14. **N .Dimitriou, A. Drosou, D. Tzovaras**, "*Scan4Reco: Towards the digitized conservation of Cultural Heritage Assets via spatiotemporal (4D) Reconstruction and 3D Printing*", to be presented at the 14th EUROGRAPHICS Workshop on Graphics and Cultural Heritage, Genova, Italy, 5-7th of October 2016, (EUROGRAPHICS copyrighted), to appear(ACM copyrighted http://authors.acm.org).
15. **Ciortan I., R. Pintus, G. Marchioro, C. Daffara, A. Giachetti, and E. Gobbetti**, "A Practical Reflectance Transformation Imaging Pipeline for Surface Characterization in Cultural Heritage", to be presented at the 14th EUROGRAPHICS Workshop on Graphics and Cultural Heritage, Genova, Italy, 5-7th of October 2016, (EUROGRAPHICS copyrighted), to appear (ACM copyrighted http://authors.acm.org).
16. **G. Karagiannis, M. Stefanidou, G. Apostolidis, K. Matziaris**, "*Application of acoustic microscopy technique for the evaluation of the optimal application of the rendering to masonry*", 4th Historic Mortars Conference (HMC'2016), Santorini, Greece, 10-12th October 2016.
17. **Bui Minh Vu, Tejas Madan Tanksale, Philipp Urban and Shigeki Nakauchi**, "*Visual perception of 3D printed translucent objects*", 24th Colour and Imaging Conference (CIC24), San Diego (USA), 7-11th of November 2016, (FREE Access).

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18. **E. Vogiatzaki and A. Krukowski**,, *"ICT Innovation for Protection and Restoration of Cultural Heritage: Horizon 2020 SCAN4RECO Project"*, to be presented (pending confirmation) at the Networking Session of the Europeana Space 3rd International Conference on Cultural Heritage: Reuse, Remake, Reimagine, Hamburger Bahnhof - Museum, für Gegenwart in Berlin (Germany) on the 22nd of November 2016 (Open Access for self archiving)
19. **R. Pintus, I. Ciortan, A. Giachetti and E. Gobbetti**, "*Practical Free-form RTI Acquisition with Local Spot Lights*", in Proc. of Smart Tools and Apps for Graphics (STAG 2016), to appear.
20. **Krukowski Artur and Emmanouela Vogiatzaki**, "Improved *High-Resolution3D Modelling of Cultural Heritage Objects by Combining 2D Raster Images with Rough Depth Information: Horizon 2020 SCAN4RECO project*", to be submitted (pending confirmation) for the 12th International conference on non-destructive investigations and micro-analysis for the diagnostics and conservation of cultural and environmental heritage (ART'2017), Sharjah (United Arab Emirates), American University of Sharjah, 7-9th of March 2017 (Open Access licensing TBC)

Questions & Answers

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