Technical Visualizations of Easel Painting. Integration of Imaging Techniques and Textual Repertories

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Abstract. Technical visualizations (TV) of easel painting, both partial or extended, are typically concerned with prospecting its structure, technique, material composition and eventual posterior interventions in order to facilitate the mapping of its characteristics being identical to those of other similar objects. For both types the main challenge is being able to integrate and compare the significant increase in the quantity and quality of image-based data resulting from rapid technological advancement in recent years. Their second critical component matches the algorithm of logical processes that, in principle, should be followed by analysis of a specific artistic technique on a unique artefact. The third crucial point is the translation of interdisciplinary to schematic or image-based data and the standardization of dictionaries used to enable their sharing. TVs are functional to the understanding of complex cases and, although the reliability of their issues is not absolute but only a *nulla osta*, they represent an important step towards the drastic reduction of errors produced by discontinued, fragmentary experiments in dating and authentication of easel painting.

Keywords: Data Repositories, Imaging Techniques, ICT, Easel-Icon Painting.

1 Introduction

Technical visualizations (TV) are typically concerned with prospecting the structure, technique, material composition and eventual posterior interventions of an artefact in order to facilitate the mapping of its characteristics being identical to those of other similar objects or to establish its status of conservation, presence of damages, their character and origin. The solution of the identity question can be limited to determined details of the work or require extended comparisons, hence TVs could be subdivided into two main categories: partial and identifying, extended. As in reality it is impossible to isolate them, the first being constructive elements of the second, in this

paper we advance a general model of their interrelations that will be used for the elaboration of tools in support of attribution, conservation and restoration of easel/icon painting [1]. The implementation of these objectives is partially funded by COST TD121 COSCH and will benefit from the technological section of the BIDL project [2][12][13], at the same time contributing to its further development as well as to the realization of the wider IFIDA programme, presented at the DiPP2014 conference [3].

In the recent past, for the visualization of otherwise invisible chromatic, spatial etc. relations in the artefacts usually graphics, schemes, or tables were adopted, together with the spectral and structural imaging and post processing techniques already well affirmed in icon expertise. In some sectors indirectly linked with ours, like investigation of ancient glass and enamels, of organic material (in computational analysis of IR spectra of complex molecules, for example of cellulose, resins, gums, organic dyes), or for reconstruction of ancient archaeological sites, the referential databases documenting various technical parameters have accumulated so much material that the application of computational methods for its elaboration has also been launched [4].

Mass introduction of any kind of analytical techniques in the study of cultural heritage (CH) continues to produce increasing rates of extremely inhomogeneous information that necessitates an increase in the sophistication of the technologies applied to its storage and efficient assessment, articulation, as well as interconnection with already existent repertories. Furthermore, the new modelling principles are not directly convertible with the already existing ones and require complementary processing of older repertories in order to be able to reuse them. The unrepeatability of each artwork additionally complicates the situation and hinders application of generalized procedures, adoption of universal models and common languages. For all these reasons, a periodical theoretical assessment of the state of the art, on a shared international level as this conference offers, appears more than reasonable in order to be able to examine and reconcile existing practices and pin-point common strategies for optimal knowledge representation, overwhelming geopolitical and linguistic barriers and assuring interoperability between the various systems.

2 Models for Technical Visualizations of Easel/Icon Painting

Theoretically, TVs are subdivided in two main categories: partial and extended. The first is needed to confirm or exclude the presence of a determined property, to establish the material, the changes in the composition, or the technological diversity of single elements. The imaging technology and imaging modalities employed to this end by single investigative methods may be completely or semi-automated. The second type of TVs is a complex process of interdisciplinary, multi-functional image-based data extraction and merging aimed to clear the internal relations of the components: spatial, metric, topological, chronological, of part hood, location, authorship, etc. Due to the non-repeatability of each artwork, it always requires human expert assessment and strongly depends on specialized, preregistered technical and technological information. Because of the heterogeneity of the information TVs have to

provide, and the requirements in every specific field they have to respect, as well as the need to express in conventional languages as understandable as possible, the main challenge in their elaboration is the creation of opportune ontological models for the organization and interconnection of data. The other important condition is the definition of identifiers that allow solving the aforementioned questions unequivocally, in the sector of icon painting in our case.

Multilayer easel/icon painting goes back mainly to the preindustrial epoch and is noted for the predominant use of natural materials, endemic or imported to the iconographic centres from various areas and yet not completely documented and identified. *Erminias* (technical manuals) preserved in Bulgaria, for example, evidence the exceptional enrichment of the artists and craftsmen's arsenal with materials of exotic origin: resins, gums, substances derived from distillation or hydrolysis of coniferous, some petroleum derivatives. For their ND characterization – given our relatively limited knowledge on the chemistry of natural compounds – the written technical sources are of fundamental importance and, therefore, are the first to be registered in the envisaged repertories. Actually, several countries have undertaken initiatives to this end (one notes particularly that of CICS [5]) and by ICOM even a WG was dedicated to it. Many important technical resources have been published in Bulgarian, Russian, Italian, and Serbian, but their digitization is yet not completed. Because in each country these resources are in the local language and follow individual principles, interrelation between them represents several difficulties. To avoid such obstacles, in the project advanced here we adopt Russian models well attested in practice [6] profiting also from the linguistic and scientific-technical relationships these data share (Tab.1, 2, 3).

The tables below show the consecutive stages that should be followed by investigation, analysis and attribution of paintings. Iconographic canters are presented by actual administrative maps; sublevels are selected for illustrative purposes only and are not of documentary value.

Tab.1 Main types of technological investigation

Investigative techniques
A. Non destructive
1.VIS and microscopic
• Photographic
• Monochromatic
2. UV
3. IR
4. X-ray
B. Micro chemical
• Of pigments and fillers
• Light microscopy
• Of inorganic materials
C. Physiochemical
• Of pigments
D. Destructive
• Of organic binders

Tab.2 Algorithm of easel painting investigation

Complex investigation of easel painting
A. Investigation of the support
A.1.Wooden support
• *Fagus silvatica* : Italy (6th c.)
• *Pyrus communis*: Byzantium (late 11th – early 12th c.; 15th c.)
• *Quercus*: Italy (8th and 12th c.), Athos (early 14th c.)
• *Pinus pinea, P. cembra*: Cyprus (mid 13th c.)
• *Castanea sativa,*

Tab.3 Iconographical schools

Iconographical schools
Armenia
Ethiopia
Bosnia
Bulgaria
Georgia
Greece
Israel
Italy
Croatia
Lebanon
Macedonia
Montenegro
Palestine
Poland
Romania
Russia

• Of resins and varnishes • Of plaster **Active biological contamination check-up** If deterioration was detected in the wooden support or the frame of a picture caused by wood-boring insects, and if insect species that have infested and damaged these parts are identified, this can explain much from the articles' history, previous travels and pre-existing conditions. Signs of infestation by *Lyctus spp.* (exit holes between 1.0 and 2.0 mm in diameter) indicate that these damaged items might have come from warm and dry European regions; those damaged or infested by *Anobium punctatum* (exit holes 1.5–2.0 mm in diameter), from most parts of Europe or heated spaces located in cold-climate regions (including Russia, Siberia); those with *Cacotemnus* (*Hemicoelus) rufipes* (exit holes 2.0–3.2 mm in diameter), from Central Europe, Russia or Siberia [7][8][14].	*Aesculus hippocastanum*: Constantinople (late 11th-early 12th c.), Athos (12th, 13th, 14th,15th c.), Byzance (14th c.) A.2.Textile support A.3.Metal support • Precious metals • Bronze • Niello • Enamel A.4.Stone support • Serpentine • Schist • Hematite • Sardonic A.5. Paper support **B. Investigation of the ground** **C. Investigation of the preliminary design** **D. Investigation of the gilding** **E. Investigation of the pigment layer** **F. Identification of the materials** **G. Analysis of the protective layer**	• Novgorod 12th-15th c • Pskov 14th c • Tver 15th c • Ryazan • Rostov-Suzdal' 15th-16th c • Volga 16th c • North Russia 16th c • Stroganov end of 16th-beginning of 17th c • Moscow 17th c • the Zar painters • The Armoury school 16th c • Icons from cities and monasteries near Moscow, 17th c • Palech 18th—19th c • Kostroma 18th—19th c. • *Romanovskie pis'ma* 18th—19th c. • *Pomorskie pis'ma* 18th—19th c. • *Peschechonovskie pis'ma* 18th—19th c Serbia Turkey, etc.

3 Integration of Tools, Data Repositories, and Case Studies

The main types of referential material needed in the sector are:

- issues from lab analyses and their protocols regarding pigments and inert substances in the bed layer; microscopic investigations, micro chemical analyses of inorganic materials, chemo-physical analyses of pigments and organic binders, identification of resins and varnishes; investigation of supports, stucco, eventual revetments in metal, enamels or textile;
- issues from ND and destructive analyses on supports (of vegetable and animal origin, metals) isolating layer, preparative layers, imprimatur, design, gilding, paint and protective layer; emulsions (natural, artificial, chemical); inorganic and organic (from vegetable and animal origin, synthetic) adhesives; balsams, resins (natural and synthetic); solvents (natural: terpenes', aliphatic, aromatic, alcoholic, and synthetic); oils (drying, semi drying, non-drying; etheric; drying substances, solvents); waxes (natural from animal and vegetal origin and synthetic)
- updates on the possibilities and limits of ND investigative techniques: in vis light, UVr, UVl, NIR,IR; NMR, FORS and the respective tools and protocols assimilating and confronting the results.

Further investigations of interest are:

- Principal technological types of organic pigments, methods for their preparation from natural materials.
- Principal organic pigments derived from natural colorants of vegetable or animal origin.
- Diagnostic symptoms of the different technological types of organic pigments.
- Diagnostic of organic blue, red and violet colours of vegetable or animal origin in organic pigments.
- Adopted systems for thin chromatography of natural colorants.
- Composition and chemical properties of the pigments used.
- Characteristic peaks of absorption of organic and mineral pigments.
- Amino-acid contents in animal and vegetable proteins (by weight).
- Composition of hen egg white and yolk (in %).
- Composition of gums used as binders.
- Composition of the saturated acids of oils from vegetable origin used in painting.
- Composition of the lipid complex of hen's egg.
- Composition of chromatographic mixtures.
- Characteristic mouldiness and fusion T° of natural resins.
- Chemical composition of colophony resins (in %).
- Composition of the turpentine and colophonies' mixtures of resin acids (in %).
- Composition of the mixtures of resin acids and their derivatives in the Strasburg and Venetian turpentine, in the Canadian balsam (in %), etc.
- Chemical composition of lack gums.
- Chemical composition of fresh, aged and hard/fossil Kauri gum.
- Position of the oscillation bands in the C=O radicals of resin acids and in COO- radicals of Cu resinates in the IR spectrum of the natural resins (for diagnostic purposes).
- Relation between averaged surfaces of the max peaks in the characteristic bands of natural resins' IR absorption.

4 Dictionaries

Unlike the (non-)destructive investigative techniques, registration, linguistic-philological, technical and technological analysis of the relative historic sources have been underplayed up to now, causing rough approximations and even errors in the planning and interpretation of the laboratory issues. The libraries actually in use created by various instrumental devices have not been elaborated appositely for art studies and are practically not directly usable. Great difficulties arise also from the fact that natural materials, sometimes of almost unknown composition, are registered under different dialect names, in different languages (Tab. 4).

Table 4. Dialect names of substances used by icon painters (Source: A. Vassiliev). Actually these registers are incomplete and only occasionally provided with etymological references and indications on the archaeographic sources.

А-Б-В	**Г-Д-Е-Ж-З-И**
АДЖЕМ НЕФТИЯ (adzhem neftia Bulg.)—Iran (Persian) petrol VIII &193 (289) АЛОЕ aloe – II &46 (59) АРДИЧ САКЪЗ ardic sakes: VII &135 (216); VIII & 14 (240) АРЗИКА (ardzika)—Reseda Luteola L. АСФАЛТ asfalt: VI АФИОН (afion)—Papver somniferum L. БАЛСАМИ (balsami)—Picea Abies M., Abies alba K. БАЛЖОН БИЖОН balzhon, bizhon, smirna—resina di pino, terpentina (Larix decidua M.) БАЛЪК ТУТКАЛ balak tutkal—colla di pesce БЕЗИРИ beziri (alifa) БИАДЕ (biadetto Ital.)—azzurro minerale БЛАГИЛ (blagil russ.) БРОШ brosh (Rubia tinctorum) ВАДУТЕРОН ВАДО ТЕРА ВАДОТЕРОН вадутерон вадо тера vadoteron (guado)- colore griggio ВАРЗИА vardzia (Sandalo) БАКАМ БАКАН МОР БОЯ bakan, morboya, brasil wood	ГАТОГОМА, ГАТОГАМБА, ГОМОГОТОН ГОМА ГОТА (gatogoma, gatogamba, gomogotan) gomma gutta: VIII &15 (241); X &7-12 (318-334); ГЕРАНИЯ, ГЕРАНИУМ, ГЕРАНОЛ gerania, geranium, geranol. Componente eterica dell'olio di rose, di muschkato, sdravez etc.; kraplack?? ДУДИСИЯ dudisia, (arab. Tut-i-sia) colore scuro porpora-marron: XI &39 ЕЛЕМИ elemi (gr.): diverse resine, oli e balsami, leggermente appicicanti, di origine non stabilita e diversa (le Filippine, l'America et al.) ЖИНИФРА ЖИНЖИХРА ЗИНЗИФРА (tur.) ginifra, gingihra, zinzifra, sinzhifra: bucce vegetali, o di colore giallo piщscuro del minio (vermillion, cinabro, rossetto) ЖИШГИЛ ШИШГИЛ zhishgil, shishgil; ЗАМТ ЗАМК samt, samk – gomma arabica ЗЕРДЕШАФ ЗЕРДИШАФ serdeshaf, serdishaf (tur.): radici di pianta che producono colore giallo "kurkume"utilizzato in pasticeria ЗИФТ sift – asfalto ИКИКАРДАШ ИКИКАРДАШ КЪНА ikikardash, ikikardas kana – bucce dell'albero Pterocarpus che producono rosso (sangue di fratello, corale) ИНДИГО indigo

5 Prerogatives and Interdisciplinary Value of the Repertories

The purpose of this project is to improve conditions for authenticity controls making them easily available to the larger auditorium of end users, at a sufficiently competitive level and with minimal costs, making better use of already accumulated experience and of a more common technological base. The authors' thesis is that tools for efficient non-contact investigation of artefacts are not exclusively the spectral/structural analytical techniques and the utilized instruments for themselves, but also the way in which the pre-existent and new generated data have been assessed and interconnected. Therefore, for transforming these informational resources in real

knowledge, their mass storage and interactive art historical, technical, and technological assessment is of fundamental importance. As correct documentation and scientific attribution of ancient works of art requires the processing of relevant amounts of images and interdisciplinary data usually kept in incompatible formats and objects of different property, we would like to profit from the periodical encounters provided by this forum and solicit their publication or sharing for the purposes of this project that will also have to assess a range of issues related to data integration generated by routine ND methods (micro and macro imaging, surface analysis, UV, IR. XRF, X-ray, CT, microanalysis), review exemplary work on image representation and mapping functional to attribution, conservation and restoration, and discuss the challenges that these techniques may bring.

In particular, it focuses on simultaneous visualization of relations concerning authorship, location, parthood, using stratigraphy, chronology, topology using pixel maps, graphic models, stratigraphic segmentation, fragmentarization, colour coding and coordinate system with fiducial points—for evaluation of variable factors in the identifying attribution. Together with partial visualizations needed to establish the dendrochronological species used for the icon support, revealing presence of biological contamination or the composition of painting materials, these TVs have to answer, for example, questions such as: were the changes in the composition *pentimenti* or determined by other (i.e., commercial) intentions; does the heterogeneity of the materials mean that the single parts were carried out in different epochs, and consequently, that the work must be considered non-original or fake.

The development of contemporary IT solutions for data and knowledge sharing and distribution for CH preservation, reuse and integration is of major importance. The solutions will maintain interactive use of CH data and their processing and analysing. The understanding of historic and natural materials, art technology and techniques, chemistry of natural compounds, authorship, iconographical schools, etc. could be contributed by IT solutions [9][10]. For example, in order to avoid duplicate image objects in BIDL (it would also concern authorship, iconographical schools, fakes, etc.) a service that checks the similarity between images is provided in the content creation process (Fig. 1). The next part presents its algorithm.

Caching images for optimizing their comparison

1. All images are resized to $n \times n$ pixels. So we get the following matrix:

$$p = \begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & \cdots & \cdots & p_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ p_{n1} & \cdots & \cdots & p_{nn} \end{pmatrix},$$

where p_{ij} are pixels, each of them with values of red, green and blue ($p_{ij} = \{r_{ij}, g_{ij}, b_{ij}\}, \; 0 \le r_{ij} \le 255, 0 \le g_{ij} \le 255, 0 \le b_{ij} \le 255$)

2. Create M (Going to grayscale)

$$M = \begin{pmatrix} m_{11} & m_{12} & ... & m_{1n} \\ m_{21} & ... & ... & m_{2n} \\ ... & ... & ... & ... \\ m_{n1} & ... & ... & m_{nn} \end{pmatrix},\ m_{ij} = k_1 r_{ij} + k_2 g_{ij} + k_3 b_{ij}$$

k_1, k_2, k_3 are coefficients for translating from RGB to grayscale.

Standard coefficients are $k_1 = 0.3, k_2 = 0.59, k_3 = 0.11$, $0 \le m_{ij} \le 255$, so $\sum_{i=1}^{3} k_i = 1$

3. Create the series (row) $M_1 = \{m_{11}, m_{12},..., m_{1n}, m_{21},..., m_{nn}\}$

Sort M_1 in ascending order and find the middle element(s). If n is even, then the middle element is m_j , where $j = (n^2 + 1)/2$ in the sorted series $M_1 = \{m_1, m_2,..., m_{n^2}\}$ and the average value is $m = m_j$. If odd, then the middle elements are m_{j_1}, m_{j_2} , where $j_1 = n^2/2$ and $j_2 = (n^2/2) + 1$ and the average value $m = (j_1 + j_2)/2$.

Now, create

$$B = \begin{pmatrix} b_{11} & ... & ... & ... \\ ... & ... & ... & ... \\ ... & ... & ... & ... \\ ... & ... & ... & b_{nn} \end{pmatrix}, \text{ where } b_{ij} = \begin{cases} 1, m_{ij} > m \\ 0, m_{ij} \le m \end{cases}$$

The matrix B is our cache for an image object.

Now, we can compare it to the caches of other objects and find the level of match (in %).

In our current case we use $n = 64$. So the cache size is 64×64 bits, which makes 4096 bits or 512 bytes. This small cache size guarantees us good performance when comparing images.

The presented service doesn't use any previously created technical metadata for the images during their comparison. A similar service could be implemented by comparing the MPEG7 metadata descriptors for the selected media objects.

In order to contribute for the generation of new, more rich, complex inter-sectorial and multi technical tools for ND monitoring of paintings in general, the authors envisage the possibility to produce referential standards, guides, software, interactive videos, etc., that benefit new scholarship, research and developments in interpretation. Particularly challenging for the authentication certification is to successfully establish the speed with which particular alterations and damage have occurred, and for the

preservation, the tracing and reconstruction of the metamorphosis the entire work has underwent in the course of its historic vicissitudes.

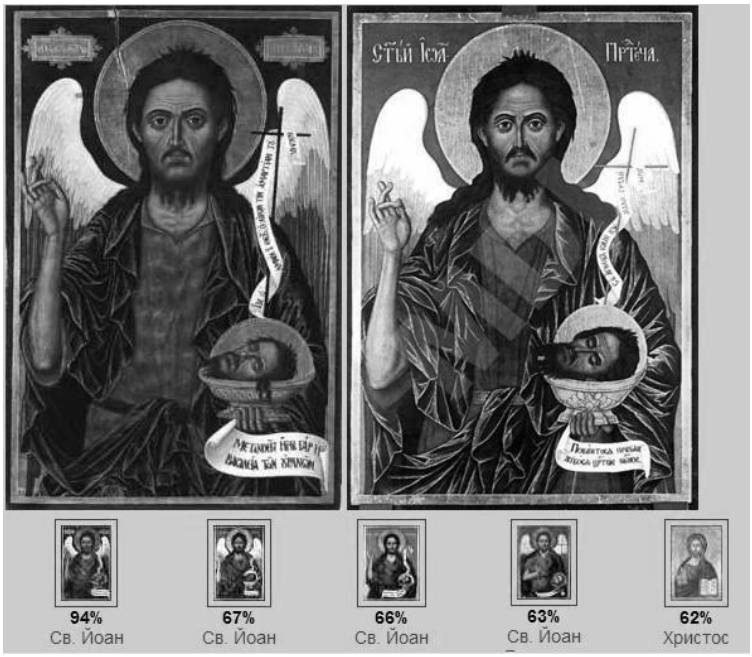

Fig. 1. BIDL Service for images similarity checking

6 Conclusions and Future Work

Further perspectives for interdisciplinary application are opened by the metadata that can be extracted from true-to-original preserved items, not only for art heritage preservation, but for the natural sciences field in general. Due to the relationship of orthodox art with other cultures, such libraries will have direct positive impact also on the DiPP of CH belonging to other cultures, such as Western European, Hebrew, Russian, Armenian, and African.

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