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Introduction – General reports

Poster session opening speech

Václav Jehlička

Senator of the Parliament of the Czech Republic
Chairman of the Committee for Education, Science, Culture, Human Rights and Petitions
(Since 2007 Minister of Culture of the Czech Republic)

Dear President of the Czech Academy of Sciences
Distinguished Representatives of the European Commission
Ladies and gentlemen, dear guests,

It is with great pleasure that I welcome you at the opening ceremony of the first scientific session – a poster exhibition – of the 7th European Conference on research into cultural heritage.

This outstanding conference is organized in order to support protection and safeguarding of cultural heritage as a tool, a facilitator and a guaranty for the understanding and viability of our common enlarged Europe. Cultural heritage is such a natural, all-encompassing and continuously changing part of our life that in many cases we do not recognise all the threats that endanger it. Though the diversity and richness of the cultural and natural heritage is immense, it is fragile and easily vulnerable. The pressures of development and the impact of climate change make it necessary to adopt of protective measures, as well as changes in policy and a society management approach.

Today we cannot imagine effective resistance to these treats without strong international research – from fundamental research to pilot projects. The results presented at this conference show that the twenty-year-old decision to launch joint research programmes was a correct and effective step forward. The results might have been even richer if the field of cultural heritage had gained higher priority. However, even the achievements presented here are admirable.

My deepest experience with cultural heritage problems concerns historic cities. I served as mayor for many years in one of the Czech World Heritage Cities inscribed on the UNESCO list. Nearly all problems of caring for cultural heritage are condensed in historic cities and in their interaction with the surrounding countryside and environment: problems of the exploitation and use of monuments as important living elements enhancing the quality of life. At the same time, historic cities are very anxious to create their local policy on the basis of research findings. Our experience of applying scientific results is mostly very positive, and we will be very pleased if an appropriate space for research on the multi-faceted problems of historic settlements is created in future European research plans. The interface with the surrounding countryside also needs to be reflected. Numerous tasks and problems emerging in historic cities remain to be resolved, though we European citizens spend most of our working time as well as

much of our free time in them. I believe that the Czech delegates in the European Parliaments will support the inclusion of a good range of thematic tasks related to cultural heritage in the negotiated calls of the 7th Framework Programme of European research and development.

Ladies and gentlemen, let me invite you to examine the results of recent and ongoing research projects supported by the European Commission and by the national research programmes. It will be my pleasure to visit the exhibition with you, and also the demonstration of new technologies in the demonstration saloon. Thank you for your attention. I wish you a successful conference and a pleasant stay in Prague.

Cities, Villages and Landscapes

Jacques Teller

CERMA umr CNRS 1563, France

Key words: urban planning, historic cities, integrated conservation

1 Introduction

The theme Cities, Villages and Landscapes brought together a selection of various and diverse posters, ranging from the conservation of ancient drainage tunnels in the Mediterranean basin to the use of new Web 2.0 techniques for identifying emerging cultural attractors within cities. A strong diversity could also be observed in research organisations. Some posters were indeed developed by individual researchers while other ones were presented by European-wide consortia. A poster dealing with the issue of conservation of European Landscapes is quite exemplar at this regard as this research. Supported by COST (Action A27), this research is based on a network of some 70 research institutions and 300 researchers (Orejas et al.).

This diversity was somehow reflected in the title of the theme which could be understood as the aggregation of three distinct scientific objects: cities, villages and landscapes. Still it has to be stressed that the articulation between these three scales is both a distinctive attribute of the European territory and a serious challenge for contemporary urban planning, as there is a strong interdependency between these three realities. An increased mobility and access to modern communication facilities indeed dramatically transformed the inner economy of most villages. Some very small villages are now even attracting international emigration – which may be a deliberate policy to maintain their population base as in the case of Spanish villages threatened by rural depopulation [1]. As a result these entities can no longer be opposed to urban settlements in terms of habits, functions or populations. In the same time, urban regions tend to polarise larger and larger territories which further contributes to the urbanisation of distant rural settlements and the subsequent transformation of many landscapes. The territories which stay apart this process are often facing serious challenges as new economic services tend to concentrate in most accessible nodes and agriculture no longer provides sufficient resources to maintain prosperous rural communities and landscapes.

Cities, villages and landscapes are the result of specific social, economic and environmental interactions. As such it can be expected that they all evolve over time so as to keep reflecting a society's values and ambitions. Still the pace of present transformations somehow appears out of control. Although they largely contribute to the changes by their individual behaviour, there is a growing fear amongst citizens that local identities might result altered or diluted by this overall process. At the opposite, freezing the transformation process of some parts of the territory considered as mere relics of our past induces a risk of alienation from those who are precisely supposed to keep it alive, active and meaningful.

In these conditions, it is not surprising that socio-economic issues underlying heritage conservation were addressed by most posters presented in this theme. This certainly constitute a key dimension of research in this field, which was already identified during by the

SUIT European project (2000-2004) [2]. This project aimed at establishing a flexible and consistent methodology to assist with the active conservation of urban historical areas. The methodology has been designed to help municipalities and local authorities in assessing the suitability of new urban developments. It further proposes to match existing historical areas with current socio-economic requirements (<http://www.suitproject.net/>).

Posters of the theme (Table 1) mostly addressed small- and medium-sized cities located at the periphery of the European Union, in the Mediterranean basin, the North of UK or Russia for instance. This can probably be partly explained by the fact that various researches presented during the poster session were supported by either Interreg or Euromed funding, which are largely inspired by the European Spatial Development Perspective (ESDP). This strategic document actively promotes a balanced polycentric development of the European territory.

Table 1: List of posters for the session Cities, villages and landscapes

Poster title	Authors
Interfacing research and risk management for a better safeguarding of cultural heritage	Brokerhof, Michalski, Pedersoli and Waller
Terezín/Theresienstadt: A European Monument	Debold-Kritter, Polívka, Rahn
MEDISTONE: A new research program on the preservation of ancient mediterranean sites in terms of ornamental and building stone	Dessandier et al.
Image and Heritage	Christine Estève
The Research Work on the Monastic Complex at Žiče with the Help of the Means Provided by the Culture 2000 Programme	Golež, Badoviac, Mauko, Shepard
Economic Instruments in Urban Planning for Urban and Rural Character Protection	Kotíková
Conservation Of Garden Monuments In Austria Recent Developments	Krippner, Licka
FOGGARA Inventory, analysis and enhancement of traditional water techniques of European and Saharan drainage tunnels	Laureano
Rescue of Russian estates of Kazan city region: problem and perspectives.	Mityashin
Conservation of buildings, with Oulu as an example	Niskala
Coordinating diversity. Landscape as common and multi-faced cultural heritage	Orejas, del Árbol and Sánchez-Palencia
Monasteries as a Part of Cultural Heritage in Russia and Europe	Sevan
Materials, Scale and Density – the Grounds of Good Neighbourhood in Finnish Wooden Towns	Suikkari & Reinikainen
Heritage Led Regeneration: Safeguarding through Investment	Sutherland and Walters
Developing a folksonomy of cultural heritage attractions	Tweed
Study of the historical buildings of Meknes (Morocco) and their alterations - Proposal of various tools for their conservation	Vallet et al
SHADUF Traditional Water Techniques: Cultural Heritage for a Sustainable Future.	Vitobello, Hassan

2 Urban planning and heritage conservation

The issue of urban planning and heritage conservation was addressed by several posters.

The aim of the INHERIT project (Margaret Sutherland and Iain Walters) is to “create the case for cities across Europe to value and invest in their physical cultural heritage as a key asset, which can form the focus for social and economic regeneration, bringing vibrancy and prosperity, as opposed to an obstacle needing to be cleared in order to make way for new construction”. This Interreg IIIc project is based on a heritage-led regeneration strategy, which has been successfully applied in Newcastle (2.000 jobs created locally, 500 apartments created in former “buildings at risk”). The project proposes to apply the same approach in three other European cities, Gdansk, Ubeda and Haga, in order to test its applicability in different social and cultural contexts. The reuse of local heritage in urban regeneration project is essential to enhance the sense of belonging to a place, especially since heritage assets hold vital importance to communities and individuals – representing and symbolising their own stories, identity and past achievements. This strategy, combined with tourism related events (fairs, expositions etc.), contributes to improve the self-image of the city and the quality of life.

In the same vein, the SUHITO project is promoting urban heritage as an asset for urban development (Risto Suikkari, Kalle Reinikainen). The objective of this project is to analyse the character of old Finnish wooden towns in order to establish key features that contribute to the local quality of life and residents self image. The density and attractiveness of different urban patterns have been compared through both density indicators and structured inquiries. Results clearly show a preference of the population for dense, multi-functional areas that can be found in old wooden towns. The survey further reveals that the social character of their neighbourhood is highly valued by inhabitants of historic towns and should hence be cared for as suggested by the INHERIT project. The study also encourages the idea that features from preserved Finnish urban environments could be applied in modern town planning, which would require a proper design of public spaces.

Small- and medium-sized cities are probably those where challenges between economic competitiveness and heritage concerns are most acute. It is especially the case for those cities that do not benefit from large tourism flows which could justify the maintenance of historic buildings. In the city of Oulu in Finland, a number of wooden 19th century houses were demolished in the city centre until the 1960's due to strong development pressures combined with a general lack of awareness regarding the heritage value of these buildings (Nyskala). As these wooden buildings are not legally listed, the authors suggest to develop adapted urban planning regulations in order to allow an increased reuse of this heritage while avoiding its musealisation. It further stresses the importance of urban planning for an improved integration of the cultural heritage within the urban setting.

At the level of larger territories, land planning has an essential role to play in order to ensure the conservation of significant pieces of landscape and views on historic cities. Tradable Development Rights (TDR) were proposed in the US in the 70's as a possible answer to increased pressure on heritage due to inadequate planning provisions. In a strict zoning system, it is hence always difficult to change the possible use of a piece of land once it has been legally allocated for development. TDRs consist in exchanging the development rights from inadequate zones (sensitive landscape areas, heritage zones) against adequate ones (planned extensions of cities, regeneration areas etc.). Eliška Kotíková suggests to apply this mechanism at the level of the entire country in order to shape landscape protection and to generate revenues that would benefit the national economy without hampering private's owners rights. The market price of tradable rights would correspond to the total demand for development (market equilibrium is established by price changes). Revenues from the sale of tradable rights could form a special fund for landscape protection programmes. In the current system, municipalities are willing to

improve territorial systems of ecological stability in the Czech Republic, but they lack money to buy out land for ecological programmes. A national TDR mechanism may then help to address this issue and to direct investment where it is most needed.

More research about urban and territorial governance is certainly required to identify best practice in this domain. It should especially aim at ensuring an increased support of the public as well as private partners for heritage conservation policies. Innovative urban planning strategies have to be adopted in the view of regenerating historic cities, redeveloping industrial heritage areas and sharing the costs and benefits of an increased attractiveness of city-regions. It is especially important in small- and medium-sized cities facing serious socio-economic challenges (unemployment, industrial decline, dereliction).

3 Ecosystemic approach of Cultural Heritage

Besides the role of urban planning for an improved conservation of heritage, several posters further highlighted the importance of past ecosystems as cultural artefacts. These contributions stressed the need of an holistic vision of the issues lying behind individual techniques and/or monuments, in a view to grasp their wider social, environmental, and economic context.

Several posters were dealing with built ensembles, an intermediate scale between the village and the city – an interesting research field where to test and develop such an ecosystemic approach of cultural heritage. Rehabilitated estates from the Kazan state in Russia were analysed not solely for their heritage value, but also their environmental, social and economic importance in the urban network prevailing before the XXth century (Ivan V. Mityashin). It is argued that, although severely affected by hundred years of disinterest, these ensembles can still play the role of multifunctional cultural nodes in innovative urban settings. This system distinguishes from other urban agglomerations by stronger relations with nature and ecology. It also differs from farms by greater cultural and economic constituent. Russian monasteries also played cultural and commercial roles (Olga Sevan). Initially dedicated to the cult, they rapidly turned into a landowning and industrial company. The commercial functions of the monastery were interrelated with the fair settlements: they leased the premises, territories, etc., combining the divine services and holidays with fairs and markets. At present both types of human settlements, Kazan estates and Russian monasteries, keep a distinctive character, due to their strong relationship with nature environment. Such built ensembles may hence be considered as kind-of laboratories for developing innovative heritage conservation policies that would embrace environmental concerns.

Two posters, SHADUF and FOGGARA, specifically dealt with ancient techniques for the management of water resources and systems as a piece of cultural heritage in the Mediterranean basin. The FOGGARA project is taking into account archaic techniques both for their practical use as water supply and their aesthetic value (P. Laureano). Foggaras are drainage tunnels which allowed oasis settlements in Algeria and the development of the Sahara. Different water techniques have been studied by this project. Analyses concentrated on their relationship with the ecosystem, the possibility of extracting resources which can be locally produced and renewed in the environment and the socio-economic situation. It is then argued that the shortage of resources is not a natural but a cultural problem due to their inappropriate use. In the same vein, SHADUF aims to contribute to the development of a bank of information on traditional and indigenous water technologies in the Mediterranean region (Maria Luisa Vitobello, Fekri Hassan). It also aims to provide a model of how archaeological data integrated with historical information and traditional knowledge could create a new sense of awareness of the role of water and wastewater in society and nature, and to integrate a long-term understanding of water management with efforts to develop sustainable development strategies.

MEKNES and MEDISTONE are targeting stone material of southern Mediterranean historic cities. The city of Meknes is rich of various cultural heritages built between the XVIth and the

XIXth centuries and notably its most important ramparts (more than 40 km length). It was protected in 1995 by UNESCO as World Heritage. An extensive assessment (Jean-Marc Vallet et al.) of the ramparts supported by GIS mapping techniques allowed to identify and ponder the various degradation factors affecting the stone and cement used in the ramparts. The atmospheric pollution, earthquakes, microbiological activity have weak degradation role in comparison with other factors like rain water impact, lack of maintenance, human activities. The authors stress that some restitution and restoration phases like some repairs using concrete or bricks increase the degradation. The MEDISTONE project was dedicated to the preservation of ancient monumental sites in terms of ornamental and building stones. The project started by identifying the origin of the stones used in three archaeological sites in order to allow adapted restoration works. It assessed different techniques for reassembling fractured and fissured stones (D. Dessandier et al.) by the use of organic products whose applicability and transposition had to be tested in the environmental conditions of the sites (especially the climate). The project finally promotes the use of cheaper local products like lime which are readily available on the market place.

This ecosystemic approach is also underpinning a research on Austrian landscape gardens. The Austrian Historical Monument Conservation Act in its actual version covers only 56 of about 1,800 garden art sites in Austria which are worth being conserved. The authors argue that this restriction must be eliminated in order to guarantee an ample conservation. Still extending this list raises important issues related to governance, ownership and funding. Actually most of the 56 sites presently listed are public. Extending the list to other parks would require either important funding for supporting costs related to maintenance and a direct collaboration between public and private authorities. This case reveals the importance of an integrated approach of conservation that may cross the traditional divide between cultural and natural policies which are usually taken in charge by different public bodies and/or institutional levels at present.

The debate around the consequences of environmental policies upon heritage conservation often tends to revolve around the notion of exception. Should heritage objects / values be exempted from environmental legislation? What is the (supposedly negative) impact of EU environmental directives upon the conservation of cultural heritage [3]? The conservation of cultural ecosystems requires a better integration between environment and cultural heritage policies, an objective that can not be achieved by enforcing more exemption mechanisms. In many cases, cultural heritage may even be considered as a reservoir for environmental best practices, as illustrated by the SHADUF and FOGGARA projects.

4 Participation and conservation

Public participation is presented in several posters as essential for an improved conservation of cities, villages and landscapes. In some cases, this issue has become central to research as in the case of the SUIT project, where participation was defined as a key element of the proposed assessment methodology [2]. It can also be more indirect, through the idea of awareness raising, as in the case of the SHADUF project. Both types of cases raise the need of improved means for public participation in order to allow an informed and mutually enriching communication between the population and the experts in charge of heritage conservation and enhancements. Surveys may appear as a possible answer to this challenge, as suggested by the SUHITO project. Though the availability of new communication systems suggest that there is room for more research in advanced heritage participation techniques.

Christine Estève describes a methodology for observing cultural heritage which leads to constitute an iconographic database related to buildings. The results are organised through “sections” which represent various forms of deterioration. All together it gives a dynamic and multidisciplinary matrix for observing the contemporary degradations of architectural heritage.

The iconographic tool composes the language that allows for debating and sharing experiences beyond geographical and disciplinary borders.

Chris Tweed suggests the use of Web 2.0 techniques for the exploratory mapping and identification of emerging cultural attractors. It is argued that without adequate informational structures, visitors are likely to focus on established attractions and perhaps fail to discover new offers that may be equally or even more appealing. Taxonomies help to structure and organise domains and have been used to help with the management and marketing of cultural attractions in the past. Internet may now help to develop a taxonomy that would explicitly relate cultural tourism attractions to the different interests of contemporary cultural tourists. This task has been developed within the context of the PICTURE project, dedicated to the management of cultural tourism in small and medium-sized cities (<http://www.picture-project.net/>).

This last experience further highlights new avenues for the use of ICTs in the conservation and valorisation of heritage. These techniques have long been confined to visualisation and didactic purposes. Using Web based techniques for identifying emerging cultural attractors may help to better match tourism offer and demand. It is also a way of alleviating the congestion charge of most popular sites by diverting part of the public to less well known pieces of heritage.

5 Role of research for an improved conservation

Urban heritage conservation has long been developed as a mere expert activity with few if any scientific research supporting its premises, rules of art and principles. There is now a general consensus that more research is needed to develop a genuine knowledge-based urban conservation. This would require adapted prediction and evaluation methods as well as a long-term monitoring of the social, economic and environmental outcomes of heritage conservation. Research is also the best way to enforce a genuine multidisciplinary of the expertise as highlighted by the conservation of the monastery of Žiče in Slovenia (Mateja Golež, Bogdan Badoviac, Alenka Mauko, Peter Shepard). The results of the research work allowed a better understanding of the building development of the monastic complex from the beginning of the construction in 1190 to the end of its use in 1782, the recognizing of historical materials, technologies of material preparation, building technology, static stability of the building, the archaeology of the church as well as its surroundings. This knowledge has been included in the preservation project of the monastery which is the basis for its further revitalisation.

Research is also needed to better assess the risks urban heritage is now faced with, may this risk be related to anthropogenic (climate change, vandalism etc.) or non-anthropogenic causes (earthquakes, floods etc.). Quite typically risk management depends on research contributions to every step in its process and a strong involvement of all stakeholders concerned in order to evaluate the expected frequencies and expected frequency of events, to manage and minimise these risks and to raise awareness about risks. In establishing the context for risk management of cultural property, research is required to ensure that all objectives and important issues are considered. Context research allows a better-focused and more in-depth risk identification by informing the construction of comprehensive sets of precise scenarios (A. Brokerhof et al.). Conversely, it is suggested that risk analysis and ranking may help to prioritise research for those institutions supporting it.

Finally, more research is needed to develop, test and document methods that can be used by other local authorities. The issue of transferability of solutions from one place to another in Europe is of great importance. As the social and legal context differs from place to place, innovative experiences are never entirely transferable from one place to another one, but lessons gained in one place should inform local authorities faced with similar difficulties. Transfer of experience is a general aim of Interreg projects, as clearly exemplified by various posters and especially the INHERIT project (Margaret Sutherland and Iain Walters). The benefits of the

Methodology proposed in this project are that it can be applied to cities across Europe as it looks at the case studies within their own individual city and regional context and seeks to look at the processes and structures which have led to success.

Such transfers of knowledge between cities is the focus of a number of current initiatives like the European Urban Knowledge Network (<http://www.eukn.org/>) or the up-coming European platform for sustainable urban development. The visibility of heritage-based experiences and researches within these networks certainly deserves to be improved.

6 European dimension of urban heritage

Most posters are based on either European (11/17) and/or international (7/17) partnerships. This reflects the above-mentioned need to share, compare and learn about experiences across Europe. Doing fieldwork in a less known social and cultural environment gives the researcher the opportunity to question the habits and presuppositions of its place of origin (Christine Estève). It further stimulates to concentrate on the aspects that are not specific to a given place, which is essential in the view of sharing knowledge. A given human artefact like the above-mentioned foggaras (drainage tunnels in the Mediterranean basin) may be preserved in some places for its aesthetical value (tourism and local identity) and in other places for its functional value (water system). Considering both types of values may help to define the most appropriate restoration techniques and to conserve the use value of this type of heritage.

Studies in the 1980's highlighted the fact that there is a specific character of European cities and landscapes, in terms of density, size and networking. More research is now needed to identify the elements that shape the identity of Europe historic towns, in the view of their best conservation and their integration in contemporary urban planning schemes.

Generally speaking, cities, villages and landscapes have an essential role to play in the European construction, as they are the material expression of a genuine European identity, accessible for most citizens. European Capitals of Culture are an important step in the recognition of the trans-national character of some cities. Accordingly the pertinence of a European-wide classification system has been discussed by some authors. This obviously raises difficulties as cultural heritage policies are strongly limited by the subsidiarity principle in Europe and listing procedures are very different from one Member State to another, both in their practice and theoretical background.

Still it should be observed that Europe has a role to play in the conservation and enhancement of cities, villages and landscapes, especially when these are characterised by conflictual identities as in the case of Terezín, in the Czech Republic (Astrid Debold-Kritter, Jan Polívka, Franziska Rahn). In-depth field research revealed the extraordinary history of this town from its foundation until today and helped to widen the image of the town, whose perception was limited to the years of the Second World War (when the fortress was used as an extermination camp). It further stressed the European significance of this monument whose multi-layered interpretation is essential for its best understanding by present and future generations. Such conflicting places could become significant meeting centres for citizens from the different countries of the European Union to establish a dialogue about their common past.

The present development of the European territory is largely based on trans-national networks of cities. These networks may be based on functional, cultural or geographic factors. They are stimulated by the increasing mobility of people, goods and services from one place to another, which constitute a corner stone of the European Union. This integration process is sometimes perceived as a thread to local identities as economic competition basically tends to hamper cultural diversity. Though it can also be viewed as a continuation of a historic tradition of exchanges and influences between cities, that the development of the nation-state somehow

shadowed in the XIXth and XXth centuries. A multi-layered interpretation of the history of our cities, villages and landscapes may hence help European citizens to better apprehend the contemporary challenge of European integration and differentiation within its wider historical perspective.

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Posters

Papyrus and InkCor go plastic

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Introduction

For most of the first half of the 20th century, it was believed that movies were an inexpensive and disposable form of entertainment. Only later we came to realize that movies are also historical records, an art form and part of our cultural heritage. In fact, less than 20% of the film made during the period of 1890-1930 survived. Of films made before 1950, only about half survived.

Early films were made on cellulose nitrate, which was highly unstable, even flammable. It caused explosions in which not only films, but also lives were lost. Non-flammable film made of cellulose acetate was invented in 1912 and introduced in 1934. It was often referred to as “safety” film, indicating its higher stability when compared with cellulose nitrate. Since the 1980s polyester (sometimes referred to under Kodak’s trade name “Estar”) has become more common, particularly for archival applications.

Although more stable than cellulose nitrate, acetate film deteriorates and releases acetic acid. This is known as the “vinegar syndrome”. Intensive research has shown that cold storage (0-5 °C, 30-40% relative humidity) might be a viable mass preservation strategy, although some studies indicate that antioxidants may also have a positive effect [1].

Basing on the research on oxidation of organic materials performed in the 5th Framework projects Papyrus [2] and InkCor [3], we report on preliminary studies of oxidation reactions during degradation of cellulose acetate and on its possible stabilization using antioxidants.

The research

During the Papyrus project, an instrument was developed, with which oxidation of organic materials can be followed in real time. The measurement principle is based on the fact that during oxidation, most organic materials emit very weak light – chemiluminescence. The emission intensity and its time dependence are indicative of the rate of processes.

In Figure 1 we can observe that light emission accompanies degradation of cellulose acetate in oxygen atmosphere and that it proceeds faster (light intensity is higher), as the temperature is increased. After the atmosphere is switched to nitrogen, the decomposition of peroxides formed as a consequence of oxidation, can barely be observed as a slight shoulder, indicating their high instability.

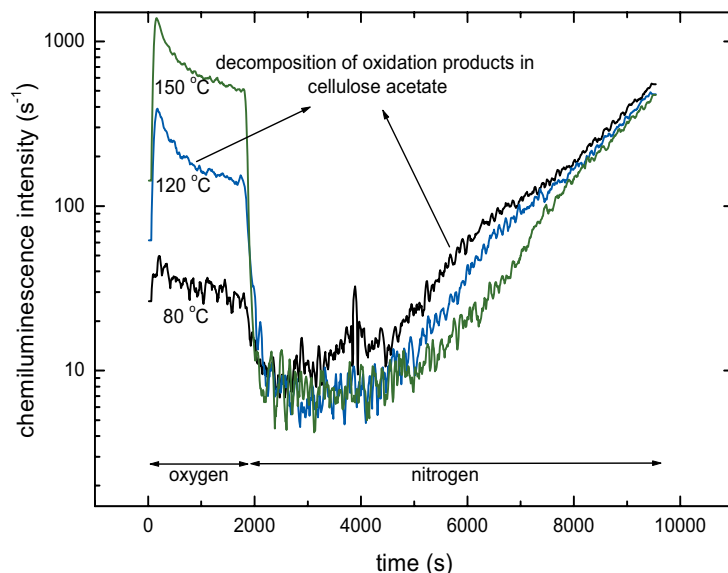


Fig. 1: Using the Papyrus instrument, oxidation of cellulose acetate can be observed in real time. The observed emission of light is indicative of oxidation processes

In the InkCor project, treatments with the aim to prevent cellulose oxidation were developed, including antioxidants. On the topic, a patent was applied for [4]. Based on the knowledge on the role of antioxidants, and based on the above experiment, we introduced them into cellulose acetate (CA) by casting from solution (8 mg CA per 20 mL CH₃CN, containing 0.1 M antioxidant) and tested several potentially effective ones. Degradation of cellulose acetate was followed using size exclusion chromatography. During a thermal degradation experiment, Tinuvin 326, propyl gallate and BHT (2,6-di-tert-butyl-4-methylphenol) showed a stabilizing potential.

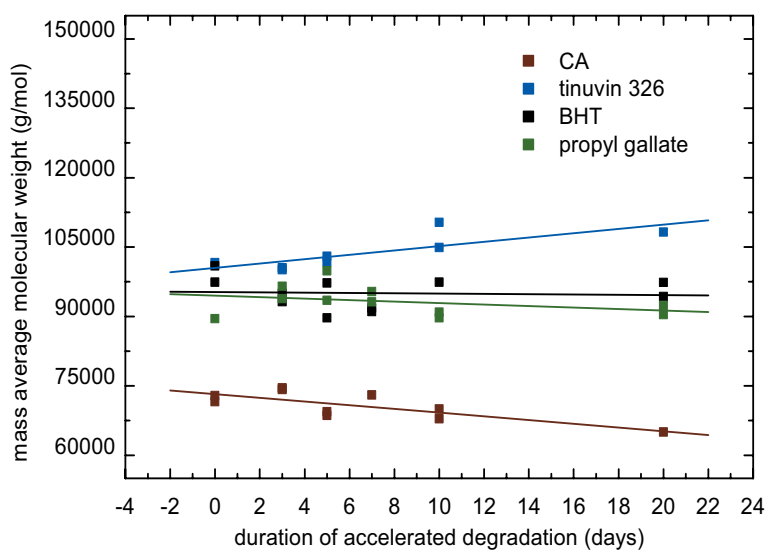


Fig. 2: Changes in molecular mass of CA films containing the indicated antioxidants during a degradation experiment at 80 °C, relative humidity 65%

Conclusions

Using the chemiluminometric instrument constructed within the Papyrus project and basing on the knowledge of antioxidants obtained in the InkCor project, a limited number of antioxidants for stabilization of cellulose acetate were tested. The preliminary results with model samples are encouraging. Further studies and conservation strategies are under development.

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ITALIAN DIAGNOSTICS FOR AN EUROPEAN PROJECT

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The Eu-ARTECH project

The Eu-ARTECH project, supported by the European Commission under the Sixth Framework Programme, defines two infrastructures for the research in cultural heritage diagnostics. One of these is a classical infrastructure, AGLAE – the Louvre portable accelerator, the other is a special infrastructure: a collection of portable analytical instruments: MOLAB (MOBILE LABORATORY). Eu-ARTECH grants researchers in the field (restorers, conservators, etc.) belonging to private and public bodies in Europe, access to twelve instruments for the non-invasive *in-situ* measurements of works of art. These devices belong to four institutions, among which the Istituto Nazionale di Ottica Applicata (INOA CNR).

INOA contributes to MOLAB with a high-resolution scanner for infrared reflectography and colour image, and a scanning micro-profilometer, two prototypes developed by the researchers of the Art Diagnostics Group.

MOLAB measurement campaigns



July 2004
Musée des Beaux-Arts et d'Archéologie
BESANCON (France)



March 2005
National Gallery
LONDON (UK)



April 2005
Archaeological Institute of Macedonia & Thrace
THESSALONIKI (Greece)



May 2005
The Hermitage Museum
ST. PETERSBURG (Russia)

June 2005
Institute of Inorganic Chemistry
PRAGUE (Czech Republic)

IR reflectography

Infrared reflectography is a well-known optical technique for non-destructive diagnostics of paintings. It enables the visualization of details hidden by the paint layers, such as the underdrawing, thanks to their partial transparency when illuminated by IR radiation.

High-resolution reflectography was introduced around the end of the 80s at the Istituto Nazionale di Ottica Applicata, where a prototype of an innovative optical device was developed.

This technique has recently been improved with the introduction of a new optical head, designed to acquire simultaneously the reflectogram and the colour image, perfectly superimposing. The technical characteristics of the IR-colour scanner guarantee, along with a high spatial resolution and a high tonal dynamics, a uniform lighting and distortion-free images. The quality of the acquired reflectogram is presently higher than that obtainable with any traditional detection system, like CCDs or Vidicon cameras.

The point-by-point superimposition of the colour and IR images allows a punctual comparison between the reflectogram and the colour image of the painting, and eases the reflectogram analysis. The high quality of these scanned images opened new possibilities and new applications for this important technique.

IR-color scanner characteristics:



Single element detection

Spectral Sensitivity: 0.9 - 1.7 μ m

Tonal dynamics: 12 bit

Max scanned area: 1m²

Spatial resolution: 4x4 pt/mm²

Stand-off distance: 150 mm

Acquisition rate: 500 Hz



The examination of the "Vergine delle Rocce" revealed two distinct underdrawings beneath the surface of the painting. Though one drawing corresponds with the final version of the painting, another shows a completely different picture of a kneeling figure, presumably the Virgin Mary with her face in near profile and the left hand across her breast.

European Project Details

EU-Artech, Contract No. RIII-CT-2004-506171, Access Research and Technology for the conservation of the European Cultural Heritage, Co-ordinator Prof. B. Brunetti, University of Perugia.

Italian diagnostics for a European project

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Key words: optical diagnostics, infrared reflectography, 3D survey

Introduction and content

The Eu-ARTECH project is an Integrated Infrastructure Initiative supported by the European Commission under the Sixth Framework Programme. Among its activities is a programme to grant access to a set of portable instruments: namely MOLAB (the Mobile Laboratory). Such a programme allows researchers, restorers and conservators, belonging to private and public bodies all over Europe, to choose among twelve instruments for non-invasive *in-situ* measurements of works of art. These devices are shared for the access by four Italian institutions, one of these is the *Istituto Nazionale di Ottica Applicata* (INOA) of the CNR.

INOA contributes to MOLAB with its *high-resolution scanner for infrared reflectography* and its *scanning micro-profilometer*. These are only two among the prototypes for non-destructive diagnostics of works of art developed at INOA during the last ten years of research activity thanks to the intensive and valuable cooperation with the *Opificio delle Pietre Dure*.

INOA high-resolution IR scanner [1] is well known in the artwork conservation field for having changed the use of IR reflectography [2]: from a diagnostic technique mainly applied to look for major changes in the painting composition (underdrawing, pentimenti), to an instrument for a detailed study of the artist's technique, through all the phases of the creation of the painting.

In this paper we present the results of the IR reflectography and the 3D survey on the *Vergine delle Rocce*, by Leonardo, done upon request of the National Gallery of London (UK) in March 2005, in collaboration with the Opificio delle Pietre Dure. This MOLAB access is an example of the importance of the joint effort of scientists, conservators and restorers for the advancement in common knowledge.

European dimension

MOLAB activities started two years ago. In this period, several MOLAB accesses enabled the study of relevant European artworks, gathering results on masterpieces of the State Hermitage Museum in Saint Petersburg (Russia), the Musée des Beaux Art et Archeologie of Besançon (France), the Victoria and Albert Museum of London (U.K.), the Moravian Gallery in Brno (Romania) and the Basilica of St. Demetrius in Thessaloniki (Greece).

In this context, the access to INOA IR scanner requested by the researchers of the National Gallery for analysing the *Vergine delle Rocce* proved to be an important European collaboration, which gave most relevant results for the study of the opera of Leonardo and moreover had a wide resonance on the media (international press announced last year this discovery of a “new drawing by Leonardo”), followed by more technical publications [3, 4].

Innovation and originality

The experience gained with the measurement campaign on the *Vergine delle Rocce*, besides the very important results obtained, is once again a confirmation of the relevance of the interdisciplinary cooperation among conservators, restorers and scientists.

IR examination of the *Vergine delle Rocce* revealed two distinct underdrawings beneath the surface of the painting. One of these drawing corresponds more or less with the final version of the painting, considered to be a copy of the Louvre painting with the same name, but the other shows a completely different and unexpected image, of a kneeling figure, presumably the Virgin Mary, with her face in near profile and the left hand across her breast. By using one of the relevant features of the INOA scanner, namely the capability of acquiring images free of geometrical deformations, the drawing was compared to other figures in different works by Leonardo, showing close resemblances with at least two of these: the *St. Jerome* of the Musei Vaticani and the figure of St. Jacob in the *Last Supper*.

Three-dimensional survey of paintings, introduced at the beginning of the 90s, has not yet reached a wide diffusion in the field of conservation. Eu-ARTECH project will also contribute to the diffusion of this useful technique. In fact, the developed micro-profilometer, by reproducing the surface morphology with a micrometric depth resolution, can be successfully applied to paintings not only for documenting and monitoring the surface roughness, but also for obtaining information related to the artwork realization, such as the traces of brushstrokes or the marks of the tools used for laying the preparation.

In fig. 1 and in fig. 2 the results of the IR scanning analysis are reported; in fig. 3 an image taken from the 3D survey is shown.



Figure 1 and 2: The “Vergine delle Rocce”: (left) dissolving view of colour image and reflectogram; (right) detail of the reflectogram of the Virgin head that shows the underdrawing of a kneeling figure with her face in near profile and the left hand across her breast.



Figure 3: Detail of the Child's head: (left) raking light image taken from the 3D survey; (centre) colour image and (right) superposition of the previous two images. The 3D survey allows to reveal the presence of retouches, such as on the Child's shoulder. The superposition of the model and the colour image eases the exact positioning of the retouch.

Impacts

The experience gained with the investigations on the *Vergine delle Rocce* proved once again how a true interdisciplinary, and international collaboration can foster important discoveries, advancing human knowledge both in art and science. This is, indeed, the inspiring principle for the Eu-ARTECH project, that for the next three years will continue to promote the use of diagnostics techniques, helping the preservation of the European cultural heritage, through the dissemination of innovative methods and instruments represented by the MOLAB infrastructure. Also important is the possibility of commercial exploitation of scientific results by European firms: in the case of the IR-color scanning technique this started recently, with the transferring of INOA's knowledge to a small Tuscan enterprise, Falcon Instruments srl, which is currently producing the first commercial versions of the instrument.

Acknowledgement

We are greatly indebted with Luke Syson and Rachel Billinge, of the National Gallery of London, for their precious collaboration and help.

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European project details

EU-Artech, Contract No. RII3-CT-2004-506171, Access Research and Technology for the conservation of the European Cultural Heritage, Co-ordinator Prof. B. Brunetti, University of Perugia.

A combined GC-MS analytical procedure for the characterisation of lipid, waxy, resinous and proteinaceous materials in a unique paint micro-sample

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Keywords: GC-MS analysis, drying oils, waxes, plant and animal resins, pitch, proteinaceous materials, paintings

Introduction and content

Samples from painted works of art are characterised by a multi-layered and multi-material nature. Priming and paint layers, over-paintings, retouchings and glazings can be simultaneously present in a paint sample. In these layers inorganic and organic substances can occur, often in mixture, as pigments, dryers, fillers, binding media, adhesives and varnishes. Proteins, glycerolipids, waxes, animal and plant terpenoid resins, carbohydrates, indigoid and anthraquinonic compounds are the organic substances commonly present in paintings. Egg, animal glue, milk, garlic, linseed oil, poppyseed oil, walnut oil, beeswax, Carnauba wax, shellac, mastic, dammar, sandarac, *Pinaceae* resins, starch, Arabic gum, fruit tree gums, indigoid and anthraquinonic dyes can thus occur in a paint sample, often in mixture.

The determination of organic materials in a unique paint micro sample is a difficult task for the analytical chemist, since natural organic substances with a different chemical behaviour can be simultaneously present. The uniqueness of paint samples together to their reduced size often requires the use of analytical approaches that permit to gain as much as information as possible on the same sample.

A novel GC-MS analytical procedure for the identification of lipids, waxes, proteins and resinous materials in the same micro-sample from painted works of art has been optimized [1]. It is based on a sample multi-step chemical pre-treatment (solvent extractions and microwave assisted chemolysis steps) that is able to separate the various organic components into different fractions, which are suitably treated and derivatised before analysis. This procedure enables the determination in the same paint micro-sample of egg, animal glue, milk and garlic (proteinaceous materials); linseed oil, poppyseed oil and walnut oil (glycerolipids); beeswax and Carnauba wax (natural waxes); shellac (animal resin); mastic, dammar, sandarac and *Pinaceae* resins (plant resins).

The sample is subjected to an extraction with an alkaline aqueous solution. In this way it is possible to separate proteins from glycerolipids, waxes and terpenoid resins. The proteinaceous material is subjected to acidic hydrolysis assisted by microwaves, and free amino acids are thus analysed through GC-MS. The residue of the extraction containing glycerolipids, waxes and terpenoid resins is subjected to a saponification/salification step assisted by microwaves with an alcoholic solution. This step allows the total saponification of wax esters [2], and the completeness of the Cannizzaro type reaction of shellac acids [3], in conditions that are suitable also for glycerides saponification. Neutral and acidic compounds are then separated through solvent extraction / acidification / solvent extraction steps and are then analysed by GC-MS.

The method was tested on several reference materials, fresh, artificially and naturally aged, prepared in accordance to old recipes in collaboration with restorers of Superintendence of Cultural Heritage in Pisa and of Opificio delle Pietre Dure in Florence. The study of these materials has permitted to build databases of reference materials, molecular markers and mass spectra, to be used for organic materials identification in paint samples. Proteinaceous materials (egg, collagen, casein) are determined on the basis of the quantitative determination of the amino acidic profile and glycerolipids (linseed oil, poppy seed oil, walnut oil and egg), plant resins (*Pinaceae* resins, sandarac, mastic and dammar), animal resins (shellac), tar or pitches and natural waxes (beeswax, carnauba wax) on the basis of the determination of fatty acid, alcohol and hydrocarbon profiles and on the occurrence of significant terpenic molecular markers. Moreover the study of reference samples allowed to evaluate detection and quantitation limits of significant compounds: on these basis it was assessed that few hundred micrograms generally are an adequate size to perform one analysis.

This procedure has been successfully exploited to identify organic materials in paint micro-samples collected from both mural and easel paintings.

European dimension

The possibility to share the results of this research with European people devoted to conservation will permit to transfer a fundamental and efficient tool for the diagnosis of organic materials in paintings.

Innovation and originality

Although in the literature many analytical procedures are reported for the characterization of organic materials in paint samples, they may generally give valuable information only on the main compounds constituting a paint sample. Anyway none of them seems capable to determine on the same microsample the presence of drying oils, waxes, plant and animal resins, pitch or tars and proteinaceous materials. Particularly, none of these procedures is suitable for the analysis of natural waxes and shellac. In fact, these materials require the adoption of specific hydrolysis conditions prior to GC analysis. Wax esters are particularly resistant to the hydrolysis step: a non complete saponification would lead to decreased amounts of waxes acids, hydroxyacids, alcohols and diols, thus giving gas chromatographic profiles that don't correspond to the actual composition of the waxes. The identification of the wax could thus be compromised, especially when small amounts are present in the samples, or when mixed with other lipidic materials. As far as shellac is concerned, the sesquiterpenoid acids originally constituting the resin (jalaric and laccijalaric acids) when submitted to saponification, can give rise to a Cannizzaro type reaction, leading to the formation of the corresponding acids and alcohols. The adoption of non suitable hydrolysis conditions could cause a mixture of reagents and products, and thus a decreased quantity of each detectable compound. Again, depending on the amount of the resin present in the sample, its identification could be compromised.

The use of an analytical procedure on a unique sample for the determination of all these materials is a fundamental aspect in the investigation of our Cultural Heritage: the amount of sample required is extremely reduced. This permit to use another aliquot of the same sample for further investigations. In addition, each analytical technique gives information only on a specific chemical aspect of the investigated material. A multi-analytical approach is thus fundamental when a deep knowledge of the materials constituting the art object is required.

Impacts

This procedure has been successfully exploited to identify organic materials in paint micro-samples collected from both mural and easel paintings. Several samples analysed came from works of art under restoration, the results gave to restorers information on the composition on

the paint and varnish layers, fundamental for the choice of proper conservation treatments. A few examples of paints investigated in the course of analytical campaigns, aimed to fully characterise materials used in the works-of-art, and to characterise technological skills of a painter or of a historical period, are showed below:

- The mural paintings of the “Stories of Teodolinda” in the Monza Cathedral were painted by Franceschino Zavattari and his sons Gregorio and Giovanni in 1444-1446. The paint surface was subjected to degradation processes, which are documented since the 17th century, and was thus subjected to several conservation treatments. In the course of the final part of the Progetto Finalizzato Beni Culturali, involving several Italian research groups, an analytical campaign was undertaken to characterise organic and inorganic materials, both original and used in past restorations. A sample was collected from a gilding of the “Longobardian Ambassadors returning to Italy”. The weight of the sample investigated was 0.2 mg and was subjected to the analytical procedure previously described: egg, animal glue, *Pinaceae* resin and shellac were identified.
- The painting on canvas, Baptism of Christ with St Lucy and St Apollonia, is located in the Santa Maria Santissima Church in Sorzano (Carrara, Italy) and was produced in the late 1600’s / early 1700’s. The painter is unknown. The painting is currently being restored and an analytical study has been undertaken to choose the most suitable conservation. A sample (0.4 mg) was taken from the white painted area above Christ’s head: animal glue, egg, linseed oil, beeswax, *Pinaceae* resin and dammar resin were identified.
- A wreck, named Dor 2002/2, was found in the Tantura lagoon, an underwater excavation located near the Mediterranean Israeli coasts, and it has been dated back to the late 1700’s / early 1800’s. The wreck was excavated by a combined expedition to the Leon Recanati Institute for Maritime Studies at the University of Haifa (Dr. Yaacov Kahanov and Ms. Deborah Cvikel), the Nautical Archaeology Society of Great Britain and the Aqua Dora Diving Centre. While excavation is still in progress, a chemical study has been started regarding the technology and the materials used in the ship’s painting. The sample weight was 0.2 mg and linseed oil and a pitch from a plant of the *Pinaceae* family were the organic materials identified.

Acknowledgement

The authors wish to thank Dr. Yaacov Kahanov of The Leon Recanati Institute for Maritime Studies, University of Haifa (Haifa, Israel), Dr. Roberto Conti, Conservator of the Monza Cathedral.

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Portable X-ray, image capture, storage and enhancement

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Key words: portable X-Ray, Digital Image storage, Image enhancement, Field work, Image Plate

X-ray radiation in general

X-radiation occurs when electrons travelling with high speed suddenly impact on a target obstacle. In *W.C. Röntgen's* experiments, the electrons were emitted by a cold cathode and bounced against a target material and x-rays are generated. These can be detected by a photographic glass plate as shown in Figure 1.

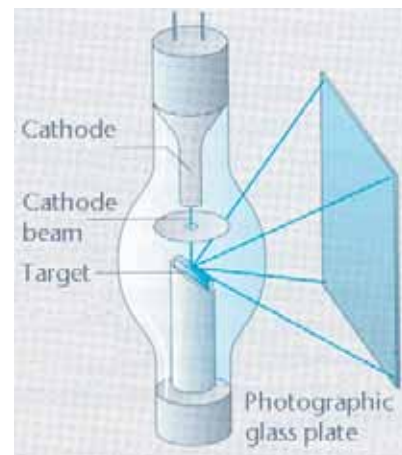


Figure 1: X-Ray tube illustration

X-ray tubes of conventional construction

Nowadays more electrons are generated by heating the cathode (3). Also the acceleration is greater (between 50 and 300 kV) as target materials, metals with a higher mass number are employed (for example tungsten) Figure 2 shows a diagram of a modern conventional x-ray tube.

1	Tube jacket
2	Focus cap
3	Heated filament spiral
4	Anode with target metal mount
5	Target metal

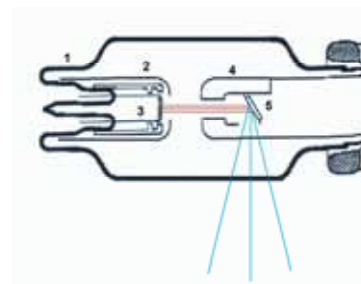


Figure 2: Schematic view of a conventional X-Ray tube

Technical background of Flash tubes

Contrary to conventional x-ray tubes, flash tubes do not carry a heating-filament (Figure 2-3) Flashtubes are cold field emission cathode tubes. Electrons are emitted directly by the cathode material. The high-voltage discharge takes place in a very short period of time. Thus an x-ray pulse (flash) has a duration of only about 50-60 nanoseconds. The impact of electrons on the anode results in the emission of x-rays. The anode consists of a pointed tungsten rod, 3 mm in diameter. As a result, the highest radiation intensity is found at the tip. This radiation is emitted through an opening in the shielding (the window or collimator) which is arranged axial to the x-ray tube. Generation of the high-voltage is accomplished by the use of a two-stepped cascading transformer with the first step being 8.000 V (16.000 V on the XRS-3) and the second being 150.000 V (300.000 on the XRS-3 generator). The duration of the x-ray process is defined by counting the pulses. The counted pulse-cycle consists of both the charge and discharge period of the primary capacitor, the x-ray flash and the regeneration-period of the cascade-

transformer and control-electronics. Depending on the battery-condition, the pulse-frequency varies between 10 and 25 pulses per second.

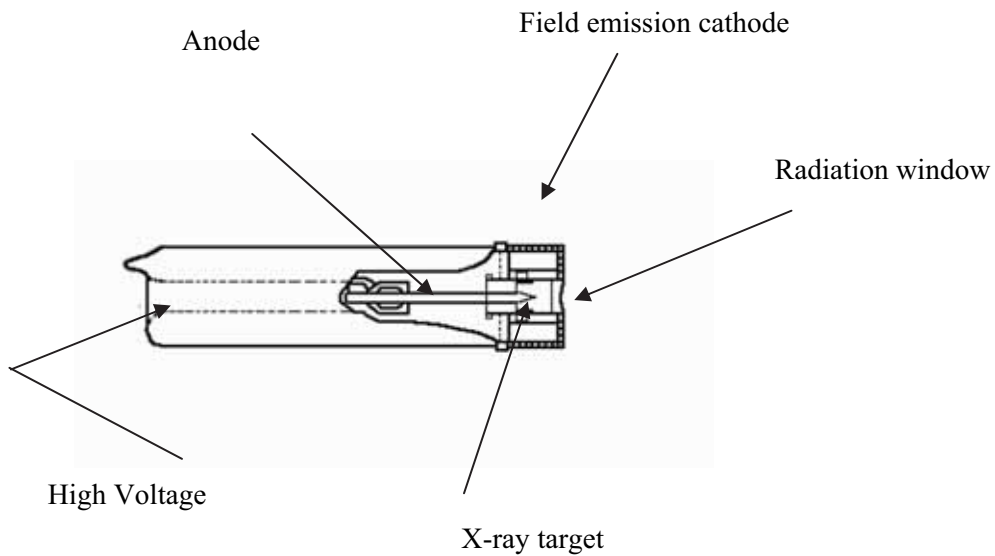


Figure 3: Schematic view of a Flash X-Ray tube

Figure 4 shows the image of the radiation cone that is emitted during one pulse directly in front of the collimator, showing the 40° spreading of x-ray beam and intensity in various areas.

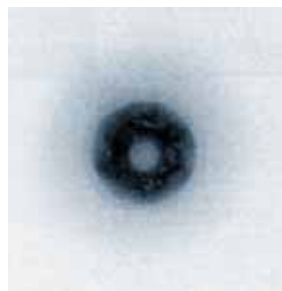


Figure 4 Radiation cone, front view – looking into the x-ray beam

Available generators



Figure 5: XR 150



Figure 6: XR-200



Figure 7: XR S3

Figures 5-7 show three different flash tube x-ray generators that are available on the market. They vary in size and capacity. The XRS 3 performs with a nominal capacity of 300 KV and XR150 and XR200 with 150 KV.

Performance / features

Type	Weight incl. Battery	Performance	Penetration (in steel)
XR-150	2.1 kg	150 KV	12 mm
XR-200	5.2 kg	150 KV	12 mm
XRS-3	5.4 kg	300 KV	25 mm

Given values are issued by manufacturer. Using more sensitive detectors like digital image plates this values may increase within limits (8-12%). Higher values found in various advertisements are technically impossible and are not supported by the manufacturer of the generators.

X-ray exposure

Extensive tests with BAM in Berlin, March 2003 came to following results.

Generator XR 200 with standard tube

Distance to front end	No. of Pulses	Energy KV	Radcal		Pen dosimeter	
			mRem	μSv	mRem	μSv
1 m	35	150	9.57	95.7	10	100
1 m	99	150	26.61	266.1	30	300

Special situation: Generator XR 200 with Beryllium tube

Distance to front end	No. of Pulses	Energy KV	Radcal		Pen dosimeter*	
			mRem	μSv	mRem	μSv
1 m	35	150	137.1	1,371.0	70	700

*Reason: Factor 2 shielding caused by Al- housing of pen dosimeter due to soft part of radiation spectrum

Generator XR S3

Distance to front end	No. of Pulses	Energy KV	Radcal		Pen dosimeter	
			mRem	μSv	mRem	μSv
1 m	35	300	12.,86	128.,6	13	130
1 m	99	300	37.2	372.,2	41	410

Max. human body exposure for professional person category A: 6 mSv, B: 1 mSv (StGV 2001/R6V)

Comparison: BAM owned continuous x-ray source

Distance to front end	Time span	Energy KV	Radcal	
			mRem	mSv
1 m	60 s	150	240.1	2.40
1 m	60 s	150	235.5	2.35
1 m	60 s	300	760	7.6
1 m	60 s	150	759	7.,6

Acquired and recorded, BAM, Berlin, GERMANY, 03.02.03 (μ = micro = 10^{-6} , m = milli = 10^{-3})

Conclusion: The values output of a pulsed x-ray source varies from 95.7 to 372.2 μ Sv as can be seen in Table 1 and 2. Compared to a continues that has a dosage of 2.40mSv the dosage of a pulsed generator is lower by a factor 10 to 20.

Image capture

- X-ray absorption
 - The weakening of X-radiation when penetrating matter is called absorption. Due to the dependence of this reduction of radiation on the nature of the

absorber, various materials can be made visible in a body, an object or a collection of different components.

- Detection and storage of intensity or energy pattern
 - Light-sensitive or X-ray sensitive surfaces, such as photographic films, are employed for radiation detection. The optical density (measure of film blackness) is directly proportionate to the radiation intensity absorbed. Electronic detection uses the memory chip of a suitably shielded video camera for receiving the intensity pattern. For direct detection a thin crystalline layer applied to a polymer matrix serves to store the energy pattern.

Image conversion / Image creation

Film application

With photographic film, a chemical development process converts the intensity pattern into a visible image. Normal x-ray films of the kind used for material testing are not suitable for use with flashtubes in view of their inertia. It was only the invention of the instant (POLAROID) developer, which is based on a amplifying sheet, that made it possible to employ photographic detectors in conjunction with flashtube generators. The film is held in a cartridge during exposure and is subsequently developed using a mechanical roller system (POLAROID process). The portable development equipment takes film size 8" × 10" (203 mm × 254 mm). The film holder consists of a robust plastic housing measuring 235 mm × 310 mm and is 13 mm thick. Due to these dimensions, there is a margin of 16 mm on three sides of the active area and 40 mm on one side. Until the end of 2001, not only 803 type film but also the transparent TPX X-ray film was available. By combining with an illuminating device and adjustable luminous intensity, it was possible to produce the subjective impression of enhanced optical recognition with the TPX film. Since February 2002 only 803 film is still available on the market.

Film cassettes and processor units



Figure 8, 9: Film Processor Type "150P"

Figure 10: Film Processor Type "Polaroid"

Video deployment

Digital video camera systems have the distinct advantage that the X-ray image can be transmitted directly to a computer or the monitor. The image can be displayed and viewed straight away for assessment and any explanation required. This technique is restricted by the use of video technology itself. The resolution of the image information depends on the chip or the PAL/NTSC conversion standards. Complex software solutions are employed to improve the "poor" initial quality of the image. Automatic image conversion and retouching processes give rise to discussions revolving around the possibility of realistic evaluation using the de-focuser and suitability for forensic purposes. However, a restriction that should not be underestimated is the fact that the integration of image information ends when a video sequence is over. The PAL video standard has a rate of 25 frames / second and NTSC 26 frames / second. The X-ray generator produces a maximum of 99 pulses. Accordingly, a video sequence in theory can only capture radiation covering 99 pulses, assuming the individual frames and the generator pulses are perfectly synchronised. However, this is not the case since the generator produces pulses of

varying lengths. Numerous video systems are based on a time window, which compares an estimated time value to the pulse length. Any undershooting of this time window and asynchronous image frames lead to “black” images, that is, exposures containing no information. Since these are integrated in the evaluation process as well, this may result in major inconsistencies in the quality of identical exposures. As mentioned above, 99 pulses are a parameter of the generator function. In the case of thick-walled objects, it may be necessary to trigger the generator several times to achieve greater penetration. Video is unable to integrate several impulse rates – only similar image files are produced, which increase the contrast, when they are superimposed one above the other, but have no influence on the penetration representation. In other words, only a fraction of the capacity of the generator (about 25%) can actually be used. The video camera is housed in a case with a fluorescent front plate. The camera captures the X-ray image at the back. To keep the depth of the equipment kit as low as possible, the image is deflected off a mirror and transferred to the CCD chip. As a general rule, it will be hard to obtain a kit less than 145 mm in depth (irrespective of the manufacturer.) A typical setup of such a video system is shown in Figure 11.

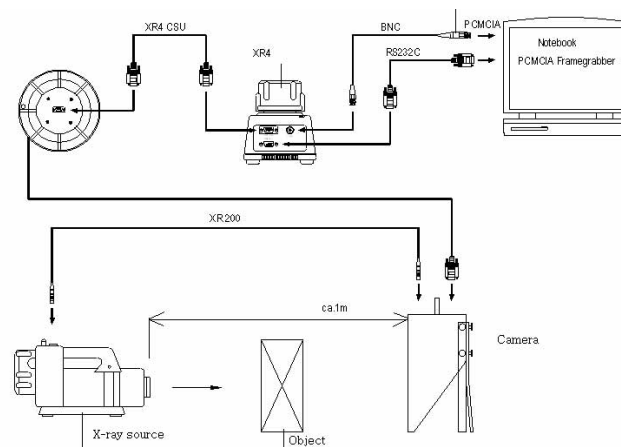


Figure 11: Typical configuration of a video-based X-ray image capture system

Digital image plates

A PVC-matrix is coated with an extremely thin layer of phosphorescent crystals. These crystals are able to capture the energy of x-rays and store them latently as an intensity map. In other words the captured energy stored in this way is directly proportional to the energy to which the individual crystal was exposed. Through the use of a red light laser, the crystals are brought into a state of instability and release blue light by reverting to their original status. The scanner reads this blue light and the software generates a readable image from the energy map.

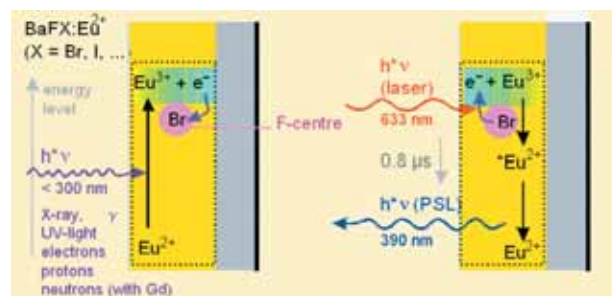


Figure 12: Illustration shows detection (left) and release of X-Ray energy pattern from an Image Plate [1] (source: K. Osterloh, U. Ewert, 1991 BAM Berlin, Germany)

The released energy of the red light laser during a read-out session is however not sufficient to erase the energy pattern completely from the image plate. Some of the crystals retain some residual latent energy. This share can be saturated or “erased” through the application of visible light energy. The alternating process storage / erasure can be repeated nearly without limits.

Light Source	Intensity [lux]	Time [min]
Fluorescent tubes	1.000	1
	2.000	0,5
Bulbs	1.000	2
	2.000	1
Sunlight	75.000	10 s*

*Sunlight is not recommended as the UV-component would be damaging the PVC matrix.

The plate is approximately 1 mm thick and can be placed easily behind an object leaning against a wall or other very narrow spaces. Two formats are available: 8“ × 10“ (203 × 254 mm) and 8“ × 17“ (203 × 432 mm). Only on the small (vertical) sides the plates carry a little plastic strip for being clipped to the scanner carousel. This allows “fitting” various images together on the computer screen. The images with 16 bit colour depth at 150 dpi are of so far unknown quality for this kind of x-ray application. 300 dpi and 600 dpi are available by software settings, but do increase the read-out time considerably. Image enhancement is available via a simple and intuitive software. For protocol proof reasons, the first scan is stored in a safe mode and cannot be modified. Any enhancement will be stored as a sub-file with its own but related file name.

Practical examples

In archaeology the system was used in order to proof that the Nydam boat (Figure 13) did not have any hidden carvings alongside the side planks as was suggested by drawings and sketches from the 19th century.



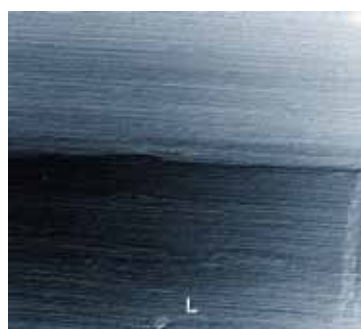
Figure 13: Nydam boat, State Museum “Schloss Gottorf” Schleswig, Germany



Figure 14: Side boards, x-ray image



a



b

Figure 15: Side board structure

Figure 14 shows the structured side plank of the Nydam boat with defined wood linings as well as a proof of sophisticated craftsmanship. Figure 15a) a photographic picture of the Nydam boat side board, b) is the x-ray image of the side board showing joining of planks. Often human bodies can not be moved and here the system proofed to be a very convenient method to operate in situ as well as in field work. Figure 16 shows the setup of the x-ray generator in front of a museum display of a human skeleton, b) shows the head stabilised with knitting needles by scientists in the 19th century.

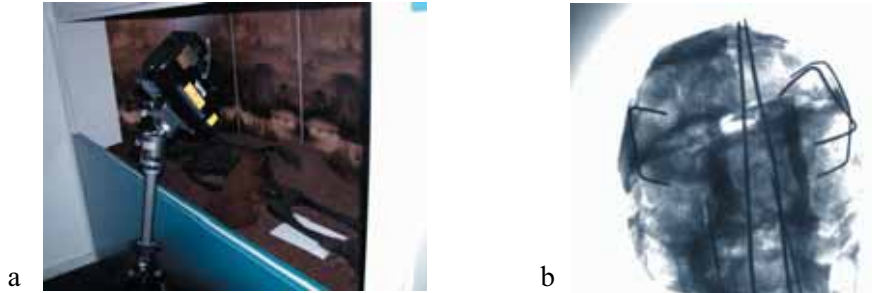


Figure 16 Human body (approx. 200 A.D.) naturally preserved in turf in northern Germany (Schloss Gottorf)

Figure 17a) shows unopened medieval amulets, b) reveals the emptiness of the container.



Figure 17: Medieval amulet (approx. 400 A.D.) size approx. 12 mm high (Schloss Gottorf)

Discussions

The easy use and handling of the x-ray generator as well as image plate and scanner are a convenient tool in various applications as shown in this paper. The results are convincing, which supports the use of such system.

Remarks

All X-ray generators mentioned and/or shown in this brochure are tested, approved and licenced by ELP GmbH at the PTB in Braunschweig, Germany.

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DEVELOPMENT OF A NOVEL METHOD FOR NON-DESTRUCTIVE STRATIGRAPHY DETERMINATION OF ARTWORKS USING ACOUSTIC MICROSCOPY AND UV/VIS/NIR SPECTROSCOPY

G. Karagiannis^{1,3}, Chr. Salpistis² and G. Sergiadis³

Abstract

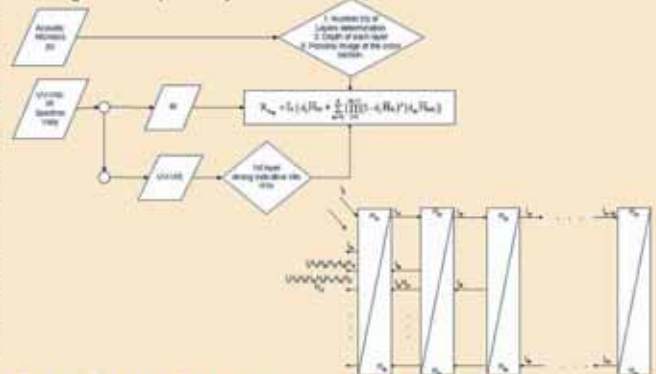
The target of this work is to develop a non-destructive testing system, which will permit the stratigraphy reconstruction of the paint layers of artworks, at any point of the painted surface. Two are the main modalities that contribute to the success of this effort: Acoustic microscopy and UV/VIS/nIR diffuse reflectance spectroscopy. The acoustic microscopy modality is used for the determination of the profile of the stratigraphy (number of layers and possibly their thickness) and the UV/VIS/nIR spectroscopy is used for the determination of the material of each paint layer. For this purpose, a macroscopic approach is applied in order to determine the material of each paint layer using signal processing and systems theory. The device used to produce and measure the backscattered light, is a Perkin-Elmer Lambda 900 UV/VIS/nIR spectrophotometer equipped with an external integration sphere for "in situ" non-destructive measurements. The total response of a stratigraphy using the UV/VIS/nIR modality, containing n layers, R_{nth} , is a polynomial with coefficients only the backward transfer functions of the consecutive sub-systems:

$$R_{nth} = \bar{I}_0 \{d_1 \bar{H}_{1b} + \sum_{m=2}^n [\prod_{i=1}^{m-1} [(1-d_i \bar{H}_{ib})^2] d_m \bar{H}_{mb}] \}$$

where I_0 is the spectrum of the incident radiation, H_{1b} , H_{mb} are vectors and d_i represents the thickness of each sub-layer/sub-system. The proposed algorithm has been tested using painted stratigraphies existing in Byzantine artworks. The measured spectra and the reconstructed ones calculated by the proposed algorithm are in good accordance. The successful matching is around 90% for the first layer determination, 66% for the second layer determination and very low for the third layer.

The algorithm

The artwork is modelled as a sequence of successive layers. Each layer is treated as an independent sub-system. Using acoustic microscopy we can obtain the number of the layers of the stratigraphy. Using the UV/VIS/nIR spectroscopy the identification of the materials existing in each paint layers is achieved.



Experimental set-up

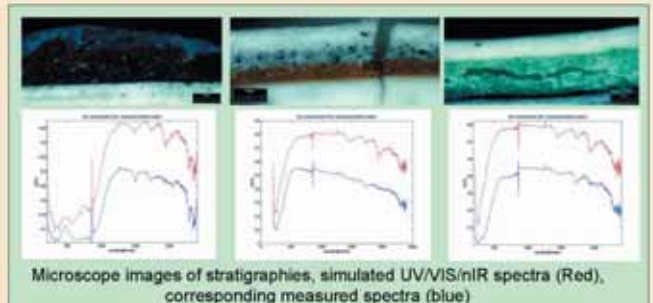


Acoustic microscope



UV-VIS-nIR spectrophotometer with external diffuse reflectance integration sphere

UV/VIS/nIR diffuse reflectance measurements



Microscope images of stratigraphies, simulated UV/VIS/nIR spectra (Red), corresponding measured spectra (blue)

Results

✓ The application of acoustic microscopy in the non destructive stratigraphy determination of artworks is proposed for the first time. The results of the acoustic microscopy are very promising for the determination of the number of the paint layers in the algorithm. The comparison of the time of flight of the echoes of the paint layers are in accordance with the calculated velocity of the sound in these materials.

✓ Even higher frequency acoustic signals must be used and examined as well, after devising an optimum way of coupling the transducer with the artwork without damaging it.

✓ The combination of the Acoustic Microscopy method with the UV/VIS/nIR spectroscopy method is also applied for the first time in this field.

Forthcoming work

✓ Integrate the two techniques in a common system in the frame of InfrArtSonic INCO-CT-2005-015338 project.

✓ Optimise the transducer design in order optimally receive the acoustic signals from the stratigraphies of art works.

✓ Extend the spectral area of diffuse reflectance measurements from 200nm up to 4500nm.

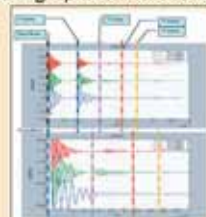


Acoustic microscopy simulations

In order to determine the system (acoustic microscope) characteristics (operating frequency, pulse width etc) the propagation of the acoustic waves in similar materials was simulated. The Finite Difference Method (FDM) is used for the simulation of the high frequency (100MHz, 250MHz and 500MHz) acoustic waves propagation in the stratigraphies of artworks.

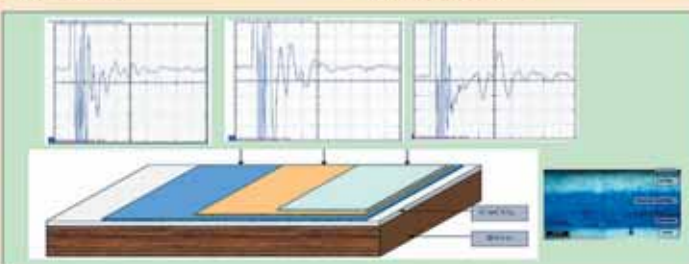
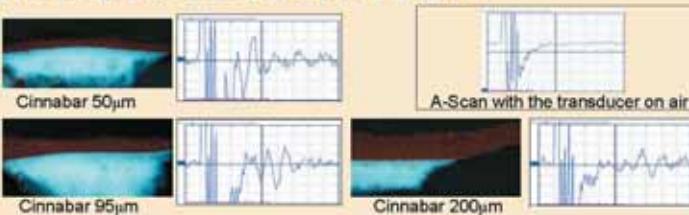


Microscope image and corresponding grey level image used for the simulation



Simulated A-Scans received from the stratigraphy (100MHz-blue, 250MHz-green and 500MHz-red)

Acoustic microscopy measurements



1. Sacred Convent of the Annunciation, "ORMYLIA" Art Diagnosis Centre, Ormylia 63071, Greece
Contact: G. Karagiannis, g.karagiannis@artdiagnosis.gr, Tel.00302371098400
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A novel method for non-destructive stratigraphy determination of artworks using acoustic microscopy and UV/VIS/nIR spectroscopy

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Key words: non destructive testing of artworks, acoustic microscopy, UV/VIS/nIR spectroscopy

Introduction and content

A main challenge for the documentation of artworks is to reveal the information that stems from the internal paint layers of artworks (stratigraphy) non-destructively. This information is mainly acquired through analytical spectroscopic methods which require a micro-sampling operation. Most of the times, the objects under study are extremely valuable and therefore may not be subjected to any intervention. This fact renders the micro sampling a prohibitive procedure. The core target of this work is to develop a non-destructive testing system, which will permit the stratigraphy reconstruction of the paint layers of artworks, at any point or at a region of interest of the painted surface. In this paper we propose the combined use of two modalities towards this effort: Acoustic microscopy and UV/VIS/nIR spectroscopy. The acoustic microscopy is used for the determination of the profile of the stratigraphy (number of layers and possibly their thickness) and the UV/VIS/nIR spectroscopy is used for the estimation of the material of each paint layer. Combining these two modalities, a macroscopic approach is applied in order to determine the material of each paint layer using signal processing and systems theory [1]. The proposed algorithm has been tested using painted stratigraphies existing in Byzantine artworks. The measured spectra and the reconstructed ones calculated by the proposed algorithm are in good accordance.

Description of the system

The artwork is modelled as a sequence of successive layers. Each layer is treated as an independent sub-system. Using acoustic microscopy we may obtain the number of the layers of the stratigraphy. Using the UV/VIS/nIR spectroscopy an estimation of the materials existing in each paint layers is achieved. Monochromatic light for each wavelength in the region between 200 nm and 2400 nm penetrates sequentially into the artwork from the spectrophotometer. The light passes through all the individual sub-systems, backscatters from each consecutive transition, and is received by the external probe of the device providing the diffuse reflectance spectra. Each sub-system (paint-layer) is assumed to have a forward transfer function H_{if} and a backward transfer function H_{ib} . Therefore, as light travels trough each layer, two light components are produced: The forward, or incident component i_{if} , $i_{if} = i_o * h_{if}$ or in the frequency domain $I_{if} = I_o H_{if}$ and the backward, or reflected component i_{ib} ; $i_{ib} = i_o * h_{ib}$ or in the frequency domain $I_{ib} = I_o H_{ib}$, where * represents the convolution of the signals, i_o the incident light and I_o its corresponding spectrum. In general, we assume that we have an n-th layered stratigraphy that we may represent as a sequence of successive sub-systems. If we have an incident radiation $i_o(\lambda)$ then the forward and backward output after the first sub-system will be $i_{1f} = i_o * h_{1f}$ and $i_{1b} = i_o * h_{1b}$ respectively. The radiation input for the second sub-system is i_{1f} . Similarly, the forward and backward radiation outputs of the second sub-system are $i_{2f} = i_{1f} * h_{2f}$ and $i_{2b} = i_{1f} * h_{2b}$, respectively. The backward radiation of the second sub-system traverses also the first sub-system. Therefore, the total radiation output from the first and second sub-layers

will be: $R = I_0 H_{1b} + I_{1f} H_{2b} = I_0 H_{1b} + I_0 I_{1f} H_{2b} H_{1f}$. The total response from a n-th layered system can therefore expressed as:

$$R_{n-th} = I_0 H_{1b} + I_0 H_{1f}^2 H_{2b} + I_0 H_{1f}^2 H_{2f}^2 H_{3b} + \dots + I_0 H_{1f}^2 H_{2f}^2 H_{3f}^2 \dots H_{(n-1)f}^2 H_{nb} \quad (1)$$

Provided that the thickness of the paint layers is between 2-100 μ m and that the horizontally scattered power of the enclosed grains is negligible, we may assume that photon energy is practically conserved. Therefore, for each layer we may accept that $\bar{H}_{1f} = (1 - \bar{H}_{1b})$. Thus, the total response of a stratigraphy containing n layers, R_{nth} , is a polynomial with coefficients only the backward transfer functions of the consecutive sub-systems:

$$R_{nth} = \bar{I}_0 \{d_1 \bar{H}_{1b} + \sum_{m=2}^n [\prod_{i=1}^{m-1} [(1 - d_i \bar{H}_{ib})^2] d_m \bar{H}_{mb}]\} \quad (2)$$

where \bar{I}_0 is the spectrum of the incident radiation, $\bar{H}_{1b}, \bar{H}_{mb}$ are vectors and d_i represents the thickness of each sub-layer. The simulated spectra are calculated using Eq. 2, the transfer functions obtained from the spectral responses of the reference panels, the number of the successive paint layers and their thickness values.

Application of the system on painted stratigraphies

In order to determine the response and the transfer function of each subsystem of a given stratigraphy using the proposed algorithm, the backward transfer functions H_{ib} of each pigment must be known. For that purpose, special reference samples were fabricated from pure pigments or mixtures of them [1], corresponding to well known stratigraphies. The reference panels are made in a way to facilitate the measurement of the backscattered response from each sub-layer or from combinations of them comprising three successive sub-layers. The proposed algorithm was tested using these reference panels. We present a few typical cases of the measurements acquired from the stratigraphies using acoustic microscopy [2] in figures 1-3 and UV/VIS/nIR diffuse reflectance spectroscopy in figures 4-7. The simulated UV/VIS/nIR spectra are labelled in red and the corresponding measured ones labelled in blue.

Results and forthcoming work

The measured spectra and the reconstructed ones (figures 5, 7) using the proposed algorithm are satisfactorily similar. In order to optimise the paint layers identification procedure, we divided the detected spectrum into sub-spectral areas between 200-400 nm, 400-1500 nm and 1500-2400 nm. In these sub-spectral areas, the transfer functions of the pigments appear to have considerable uniqueness. We simulated all the possible stratigraphies-combinations using the transfer functions for each layer from the reference panels. Each of these simulated spectra was then compared with the measured spectra of the experimental painted stratigraphies. The maximum correlation coefficient between the measured spectra and the simulated ones was obtained in the case where the corresponding layers of the stratigraphies were of the same material. More work must be done in the interpretation of the nIR information using signal processing techniques. For the time, the successful matching is around 90% for the first layer determination, 66% for the second layer determination and very low for the third layer. The next issue is the identification of each paint layer of the stratigraphy. Towards this target, acoustic microscopy was used for the first time in the non destructive stratigraphy determination of artworks [2, 3] according to the best of our knowledge. The results of the acoustic microscopy are very promising for the determination of the number of the paint layers in the algorithm. The time of flight of the received echoes is in accordance with the measured velocity of the material under study. Even higher frequency acoustic signals must be used and examined as well in the future, after devising an optimum way of coupling the transducer with the artwork without

damaging it. Finally, the combination of the acoustic microscopy method with the nIR spectroscopy method is also applied for the first time in this field.

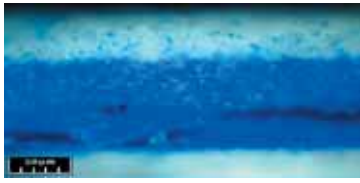


Figure 1: Stratigraphy No 90
1st (layer): Ultramarine,
2nd: Ultramarine+Lead white,
3rd: Lead White

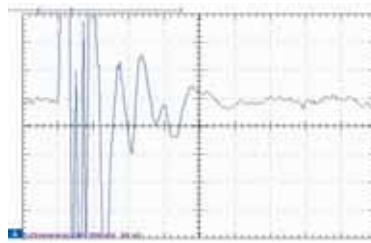


Figure 2: A-Scan from 1st & 2nd layer of stratigraphy No 90

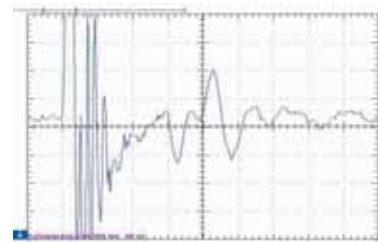


Figure 3: A-Scan from all layers of stratigraphy No 90

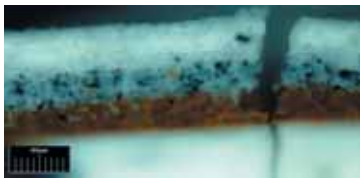


Figure 4: Stratigraphy No 104
1st (layer): Warm Ochre,
2nd: Lead white+Carbon Black,
3rd: Lead White

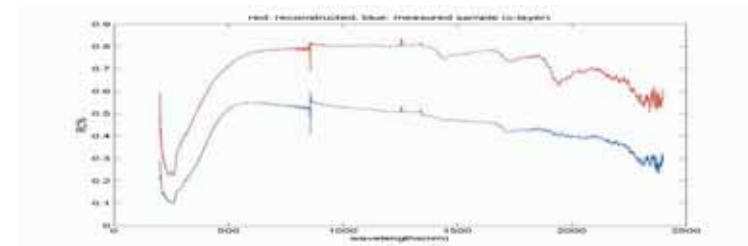


Figure 5: Simulated spectra of the stratigraphy No 104 and the measured one

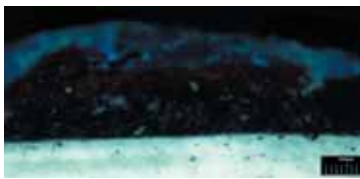


Figure 6: Stratigraphy No 122
1st (layer): Carbon Black,
2nd: Caput Mortuum, 3rd: Azurite

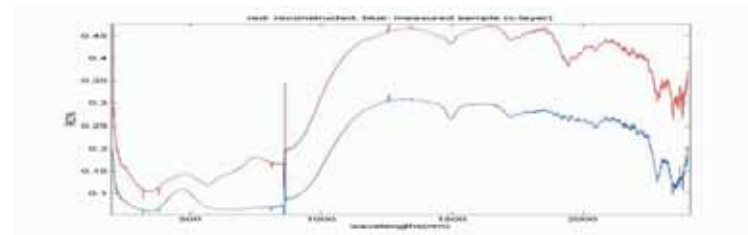


Figure 7: Simulated spectra of the stratigraphy No 122 and the measured one

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POLYCHROMY ON WOODEN LACUNAR CEILING: THE CASE STUDY OF BAGATTI VALSECCHI PALACE (MILAN, ITALY)

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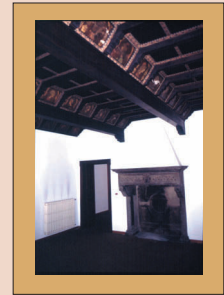


INTRODUCTION

Bagatti Valsecchi Palace in Milan is a house-museum built in 19th century, which resembles architectural elements of 16th century dwelling-places of the Lombard aristocracy. The important collection of Renaissance art and antiquities, in particular paintings and furniture, is placed in rooms decorated by **polychrome wooden ceiling panels**; geometrical and floral subjects constitute the decorating pattern. The palace has recently undergone a diagnostic campaign, focused on the definition of building techniques and degradation phenomena of the architectural elements; the wooden lacunar ceiling has been deeply surveyed. Their good state of conservation was a unique opportunity to investigate their features, seldom described in scientific literature.

Aim of this work has been the **identification of the painting materials**, and of the **decay products**, and to correlate data contained in "Art and Crafts" handbooks published in the beginning of the XX century with analytical findings.

The knowledge about the painting techniques, linked to the state of conservation detected, has been used to plan conservation strategies; a correct suggestion indicates monitoring as the most useful method to grant the best equilibrium between conservation and use, according to the museum designation of the building.



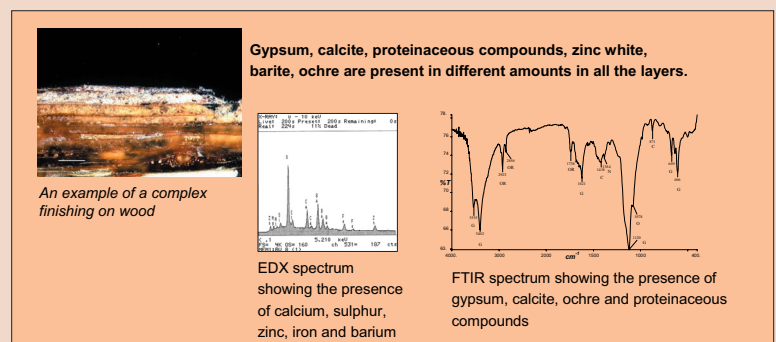
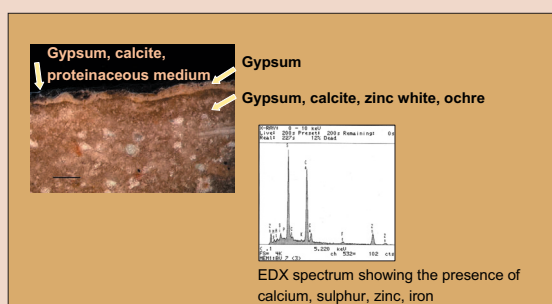
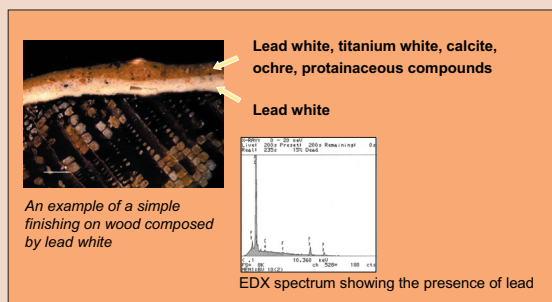
ANALYTICAL RESULTS

Infrared (FTIR), X-Ray Diffraction (XRD) and Microprobe (EDX) analyses enlightened two main kinds of stratigraphy.

A **very simple stratigraphy** constituted by one or two layers; gypsum and calcite are the main components. Pigments are always ochre which are occasionally mixed with barite, zinc white and lead white. Probably a proteinaceous compound has been used as a binder

In case of **complex stratigraphies**, the internal layers may contain gypsum, lead white, calcite, zinc white and ochre, while the brownish finishing is composed by gypsum, calcite and organic compounds. Its colour is due to different mixtures of calcite, ochre, lead white and titanium white.

As far as the **degradation products** are concerned, thenardite (sodium sulphate), calcite (calcium carbonate) and silicates are observed in **efflorescence**, while **deposit** is mainly composed by barium sulphate, nitrates and traces of organic compounds.



CONCLUSIONS

Investigation carried on polychrome wooden ceiling panels coming from Bagatti Valsecchi Palace was an unique occasion to enlighten the **Eclectic Architecture**, not yet deeply investigated

The examined finishing does not show an homogeneous composition, even if in the most of cases a mixture of lime and gypsum has been revealed, often enriched with barite, lead white, titanium white and zinc white. These kinds of mixtures are to be linked to **early industrial production**.

A survey carried out on handbooks of the period informed that lime and gypsum have been used as the main components with the role of **thickening**; on the contrary other white pigments have been used to increase **hiding power** (titanium oxide or lead white), or to enhance **transparency** (barite). At the period a **tempera medium** prepared with egg yolk was still used, witnessing the conservation of traditional painting techniques with more innovative materials such as titanium white.