TRENDS ON PHOTONICS FOR RESTORATION AND CONSERVATION OF CULTURAL HERITAGE. ROMANIAN EXPERIENCE

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Introduction

Nowadays when technology allows for complex investigations, many people, mainly restorers and researchers, know that restoration is a genuine science accompanied by artistic knowledge. This is no longer a mere craft. Any action performed on an artwork must come along with diagnoses and very accurate interpretations. Optoelectronics brings with it the benefit of such techniques and has become a very useful restoration and preservation instrument.

SAVING SACRED RELICS OF EUROPEAN MEDIEVAL CULTURAL HERITAGE – project under auspices of CULTURE 2000 Programme – developed a new and non-conventional form of cooperation between muldisciplinary teams from all over the Europe and with participation of non-European well-known specialists. The project envisages creation of the professional approach for a pertinent solving of an acute aspect in restoration process for pieces with artistic and historic value in the same time. The project focused attention on the advanced restoration and conservation strategy implemented on an ensemble of three religious sites from North of Moldavia - historical region of Romania, with contribution of the advanced investigation techniques results.

The admirable contribution and hospitality on selected locations have been offered by monasteries and churches and by CERECS ART S.R.L, mainly from prof. Oliviu Boldura – chief restorer.

This project was created with a contribution of a National Institute of Research and Development for Optoelectronics (INOE)– Centre for Restoration by Optoelectronical Techniques, National Institute of Historical Monuments (INMI) both from Bucharest-Romania, ENEA from Frascati - Italy, Institute of Applied Physics "N.Carrara", from Florence- Italy, Institute of Physical-Chemistry Rocasolano, from Madrid-Spain.

The selected monuments are: *Sucevita Monastery, Balinesti Church, Popauti Monastery.* These three locations of the important marks of the historical events that are strongly correlated with European history have strong links to *Stephan the Great* kingship and have been documented and presented by specialist of INMI, mainly by Prof. Tereza Sinigalia. Objectives' significance in the Romanian people history, in European people history, and – particularly in religious history are largely sustained by the contribution of Prof. Sinigalia.

Because of the unfriendly environmental conditions over centuries, the fabulous paintings and important collections (books, documents, textiles) are permanently stressed and exposed to accelerated degradation process. In such conditions, modern conservation strategy could benefits by modern investigation & diagnostic methods and techniques.

The project – organized as restoration *laboratory* - was started on 1st of November 2005 and had a core that brought the participants in situ in the same time and supported the good-practice demonstrations and advanced results implementation. This *laboratory* had a secondary effect, too: it strongly entrusted all categories of participants in the high quality of multidisciplinary work.

The l*aboratory* benefited by a number of advanced techniques and modern methods of investigation, diagnosis, restoration. Involved techniques generated qualitative – RH&T monitoring networks (PC compatible), laser induced breakdown spectrometery for on site pigment analysis and stratigraphy, and for polluted encrustation characterisation, laser induced fluorescence for non-contact control of surface contamination, laser range finder techniques for deteriorated surfaces.

This on-site laboratory – an atypical project - was intended as an introductory event for students and end-users interested in knowing more about the less known important pieces of the European cultural heritage, about exciting developments in this advanced high-tech area of conservation and conservation science. The project's description is available on dedicated website (http://inoe.inoe.ro/moldavia). The project was an initiative of networking to promote advanced photonics, mainly laser techniques, in conservation of artworks. These innovative instruments are considered as well-recognised tools for solving a variety of problems in conservation, such as investigation and diagnosis of artworks, statues, monuments and historical buildings, cleaning, detection of defects, in-situ analysis of composition and 3D documentation.

The on site laboratory had in view to cover simultaneously several purposes: restoration interventions presentation, monitoring of the deterioration; harmonization of the advanced knowledge and methodology developed by appreciated teams, training of a large number of participants with the aim to establish a proper knowledge and use of optoelectronical instruments and innovative methods for diagnostics, and given a high priority by the specialists of the European members of the thematic network, by Romanian specialists, , members of PRO RESTAURO – Romanian National Thematic Network (http://inoe.inoe.ro/prorestauro) and invited members of LACONA group (LASER IN CONSERVATION of ARTWORK) from Europe, USA, Brazil [1].

Photonics in Restoration – State of art

Laser techniques have demonstrated very promising applications for diagnostic and restoration purposes in art conservation. During last decade a growing interest in Europe has brought this innovative approach to be tested and validated on various important tasks: structural laser diagnostics of frescoes and art objects; compositional laser diagnostics of materials; environmental laser monitoring, laser cleaning of stone, metals, paintings, paper etc. Presently the CULTURE 2000 is giving the frame of promoting the advancements achieved in the development of new instrumentation, accumulating validation of laser based techniques with case studies, extending the use of laser for conservation throughout Europe.

Today laser techniques are being successfully employed in the conservation of a number of masterpieces in many European countries, featuring the advantage of preserving historical layers otherwise impossible, especially for stone and metals. Because of this, the general acceptance on laser methodologies by the conservation institutions appears continuously and convincingly growing. Technology transfer has been also pursued and many laser systems producers could make products out of these research projects. A permanent increasing number of professional restorers are being acquainted with these new instruments and methods [2, 3, 4].

Having in view the large and constant activities of the last years, Romanian specialists accumulated an important experience. INOE is prepared to be involved in dissemination and technological transfer activities for such innovative methods towards the conservation community. Under the light of these results, the priorities of INOE are focused on case studies and complex collaborative projects. INOE is part of European consortium concerned on still open issues and which will propose new and more advanced technologies.

Last decades an increasing interest among art historians, archaeologists conservators and scientists was shown in exploring and applying laser-based methods for Cultural Heritage. This interest generated a very active and interdisciplinary community all over the Europe, involved in research on and actual use of advanced laser techniques in a wide variety of diagnostic and conservation problems. The fundamental research is greatly devoted to the investigation of the potential of laser spectroscopic techniques (laser-induced fluorescence, LIF; laser-inducedbreakdown spectroscopy, LIBS; Raman and IR spectroscopy) as tools for characterizing the materials (e.g. LIF for pigments, binding media, varnishes; LIBS for pigments, stratigraphic analysis, on-line monitoring etc).

Advanced laser-based techniques, like 3-D scanning, holography, holographic interferometry, Doppler vibrometry, offer accurate data about the defects' distribution on surface or – even – under the superficial layer. Also, fluorescence imaging, multispectral imaging (UV-VIS-IR) and colorimetry demonstrated their success to detect underlying drawings and pigments composition in paintings.

Laser cleaning can be a tool for restorers to remove deteriorated layers that cannot be removed by conventional methods, with renowned features like: no chemical solvents, selective removal of deteriorated layers or materials due to differential optical absorption, accurate control of amount of material removed.

Lasers have significant applications in monitoring of environment effects of deterioration. The atmospheric pollutants affect the artwork in different ways and speed under different humidity and temperature conditions.

NO_x, SO_2 and some VOC are main pollutant species, responsible for the degradation of artwork objects and their recommended limits are now recommended, given by the artwork environment authorities of galleries and museums, are well below those specified for the outdoor environment acceptable for the human protection. To protect the artwork object, the indoor parameters have to be controlled and consequently they need to be monitored. In this respect, INOE installed a microclimate monitoring network in each location of the project and the dynamic of the microclimate will be study after a long term monitoring.

Optoelectronical facilities on site

The selected methods and instruments used on site - all employed in INOE's laboratory [5, 6]- are highly technical, perfected mostly in the last decade at European level. The main ones, shown in next block-scheme (**Fig.1**) and described below, are extremely versatile, addressing a wide range of materials.

Microscopic laser cleaning systems assure a high cleaning precision, but they can be coupled with other monitoring systems, starting from photo-video recordings, to *thermovision* analysis or *UV-VIS-NIR multispectral analysis*. To go with these, there are results of the latest researches: qualitative evaluation

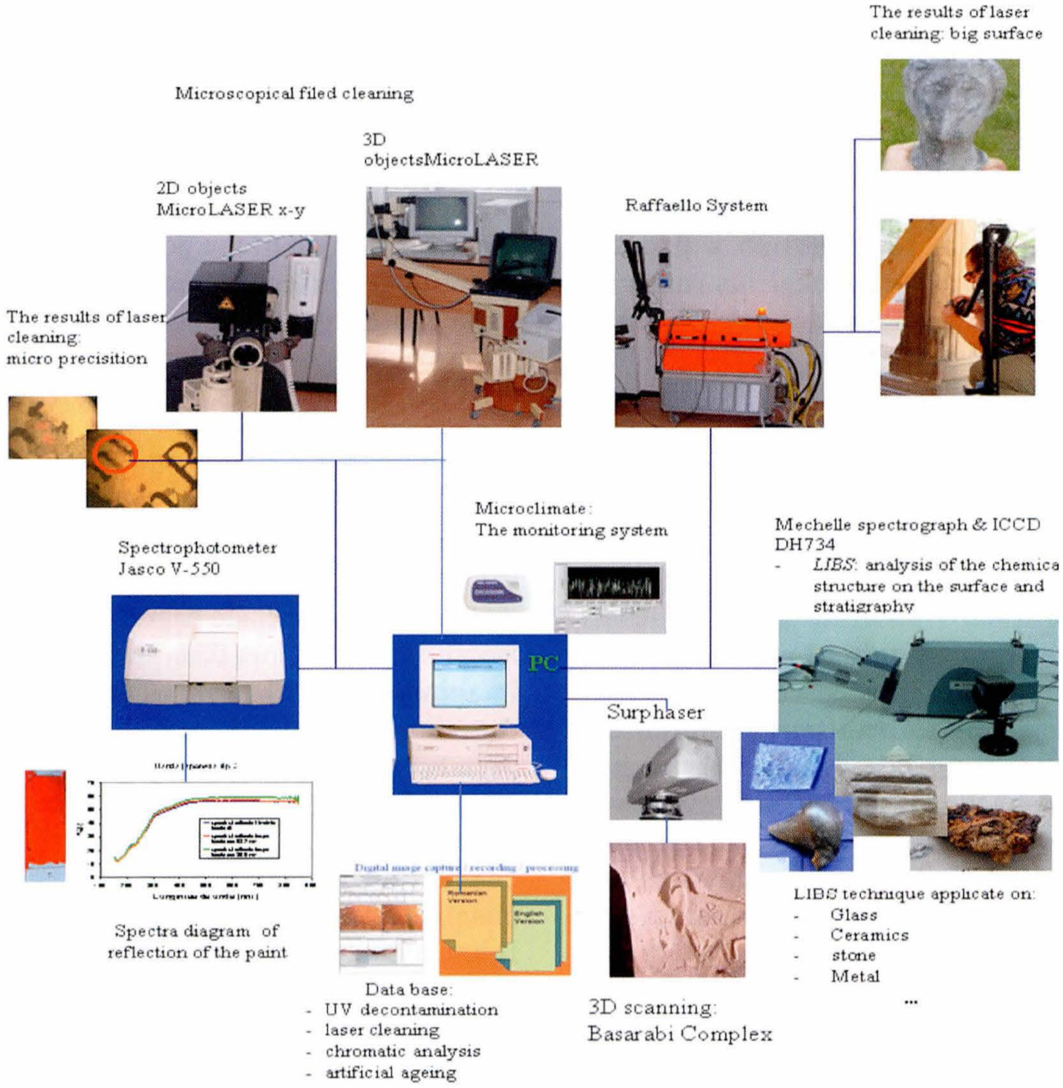


Fig.1. INOE-CERTO current activities

techniques using LIF, LIBS, LRF and 3D Scanning of large objects – including historical buildings. *UV-VIS Spectroscopy* concerning transmission and reflection spectra measurements, as well as CIELab chromatic system *Colorimetry* can also provide information helpful for artworks *composite materials and degradations characterization. These techniques that directly envisage cultural objects, together with microclimate conditions and environmental pollutant agents monitoring* establish the way our patrimony is affected. *Large surfaces laser cleaning system* is also integrated to the other operations and systems presented.

It is based on the Nd:YAG laser working at four harmonics (1064nm, 532nm, 355nm and 266nm) and it has numerous applications in diagnosis, analysis, evaluation, conservation and restoration, being adaptable to the previously mentioned techniques, too.

We must underline that optimization of the functional structure, as well as the operating precision of the techniques are established in direct corroboration with important case studies. For some of them, some examples are presented bellow.

Examples of case studies. During this project - at Sucevita Monastery's museum - *an in situ restoration/*

Table 1.

	Technique / ***Object***	**Laser Cleaning**	**LIBS**	**Multispectral images**	**Optical Microscopy**	**Colorimetry**
Textile	***Maniple***	x	x	x	x	x
	Stole	x	x	x	x	x
Paper	***Obituary***	x	x	x	x	x
Metal	***Cross***		x		x	
	Cash pot		x		x	
Wood	***Icon***			x		
	Throne			x		
Stone	***Foundation stone***	x			x	x

conservation workshop using optoelectronical techniques took place, corroborating numerous parallel activities, strongly entrusting all categories of participants in the high quality of multidisciplinary work.
In the table below are presented the artifacts provided, as well as the techniques that were applied to each one of them (**Table 1**).

Textile
Maniple

Inv. Nr. 586 / III, 18th century, provenience from Church St. Nicholas, Beresti Parish, it is kept in storage at Sucevita Monastery Museum. Manipel is a textile artefact that was worn during sacral ceremonies. It has a trapezoidal shape. It is made from white brocade, bordered with yellow gallons. In the middle it presents a cross also made from yellow gallons.

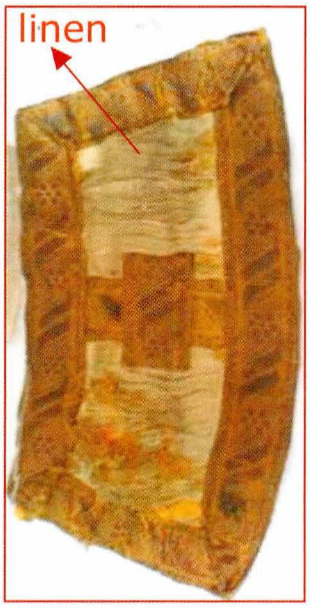


Fig. 1.1

Conservation Status: On the whole averse the textile artefact is destroyed and all it is left is the warp. We can suppose that the fibers are from linen or cotton. Beneath the warp we can actually see the textile support layer, made of linen or hemp.
Investigations:
1. PH Determinations (thanks to dr.Matija Strlic)
PH values were determined on four different spots on the averse of the maniple, and one on its reverse (i.e. white linen - 5.5, yellow threat – 5.7, support textile – 7, yellow gallons – 5.5, cotton (reverse) – 6.7)
2. Microscopic documentation – yellow gallon for conservation status of the metallic threads
Stole
Inv. Nr. 353 / III, 18th century, provenience from Church St. Nicholas, Beresti Parish, it is kept in storage at Sucevita Monastery Museum.

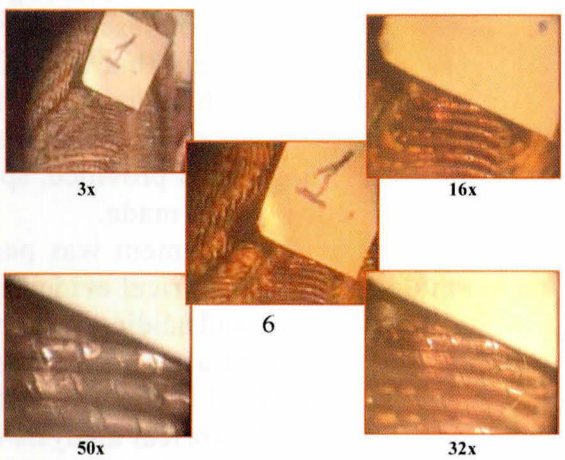


Fig. 1.2

Dimensions: - length 139 cm, width 26 cm
Avers: The stole was made of red silk or cotton brocade with metal silver thread; the technique used was *bucle k*not. The motif consists in beautiful floral ornaments. The stole is bordered by yellow gallons and the neck holder is made of red cotton.
Reverse: The textile is made of linen covered with another layer of cotton. The cotton layer is preserved only on the upper part of the stole. The whole reverse of the stole was bordered with red cotton.

Conservation Status: In the upper part of the stole the textile materials present severe deteriorations mostly from human grease. The gallon is broken in some areas. All over the stole the metal threads present disruptions. The metal threads were made from silk with silver metal foil.

Laser cleaning tests:
A series of laser cleaning tests were accomplished, at different working regimes in order to evaluate the way the laser interacts with old textile threads. Used wavelength and number pulses are mentioned for each example. The searched laser regime (laser fluence particularly) was deeply studied by co-workers in all their previous works [5]. The results were promising, as you can see in the following microscopic images:
Paper
19th century Obituary (Pomelnic)

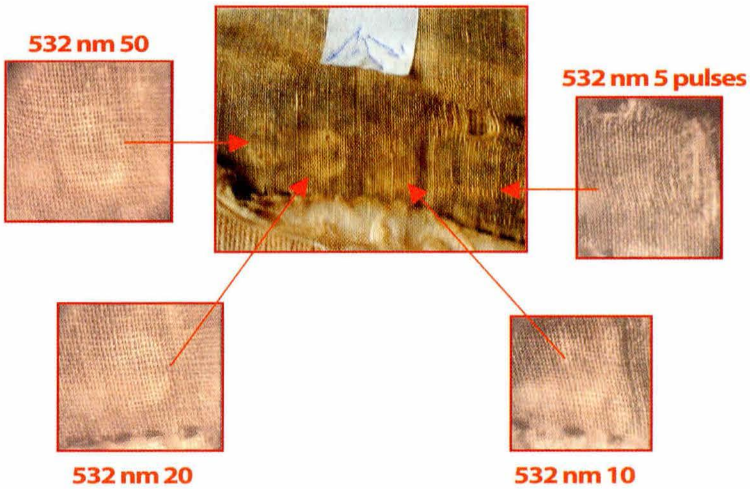


Fig. 1.3

Provenience: Sucevita Monastery, Suceava county

The document - an *Obituary* (*Pomelnic)*, inv. no. 25 - was particularly fragile, which was obviously due to very intensive use. The object was glued on a support, that was also very badly preserved, both of them being loosely glued onto a cardboard support. Immediately after the first examination, a protective envelope was made to prevent information and material loss due to handling during the workshop. Upon visual inspection it was immediately evident that several different inks were

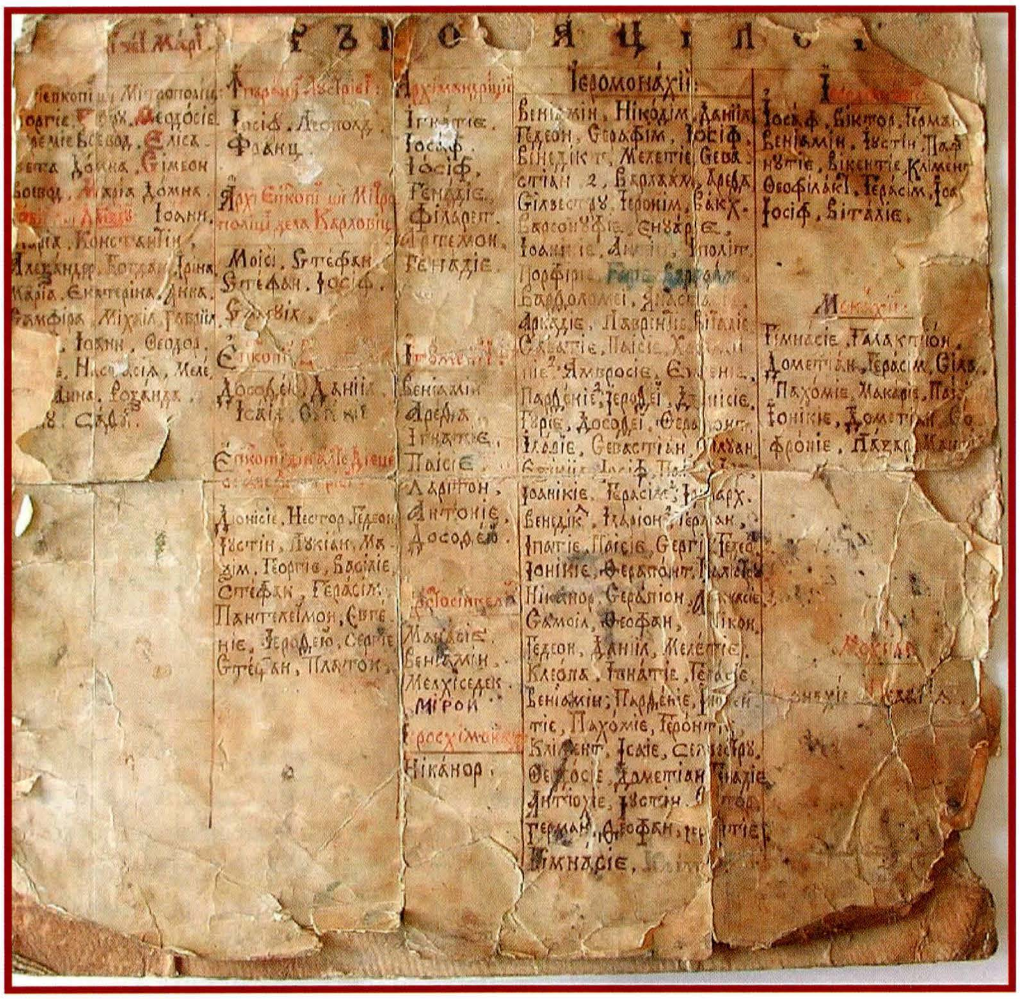


Fig. 1.4

used. They could be examined using colorimetry – thanks to Dr. Jens Hildenhagen - it was established that at least four inks were on the sheet of paper.

Multispectral Investigations:
Analyses using the imaging camera indicated that at particular places (especially where loss of material took place) in the manuscript; there is evidence of biological attack.
The presence of hyphae was indicated by very thin threads, which only became visible as they fluoresce. In this way, however, it is not possible to determine whether the microorganisms are active or not. In fact, their presence could be due to a past mistreatment.
In any case, thorough cleaning of the document would be recommended.
LIBS Investigations:

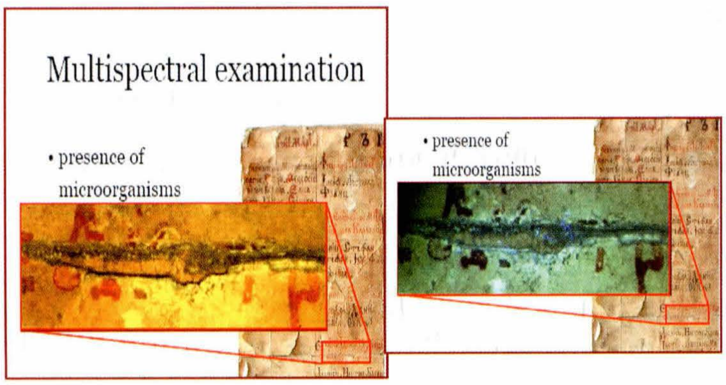


Fig. 1.5

The LIBS tests, as well as the laser cleaning ones were accomplished in collaboration with some of our international partners Marta Castillejo, Mohamed Ouija, Wolfgang Kautek and Vassilis Zafiropulos. The composition of the black ink was of particular interest, as it could be composed of iron ions and extracts of galls. The iron gall inks are infamous for their corrosion, so that it needed to be established whether the ink in question in fact contains a large amount of iron. The analyses done using laser induced breakdown spectroscopy showed that the peaks for iron were only slightly higher when inks were examined than when paper was examined. The LIBS technique was characterized as micro destructive by the conservators, as there is no noticeable damage on the artifact. Additional analyses using iron-indicator paper strips indicated no presence of Fe(II), which means that it is very likely that the ink used was a carbon-based ink, which is usually safe for paper. Also, using a portable colorimeter that our collaborator dr. Jens Hildenhagen provided, specific colorimetry determinations were made.
Approximate dating of the document was possible basing on technological and historical evidence. The paper itself is machine-made and acidic, which means that it was probably produced after 1850, when the production technology changed in the way that such paper became widespread. Historical analysis of the document made it evident that the *Obituary (Pomelnic)* was used during ceremonies and that it

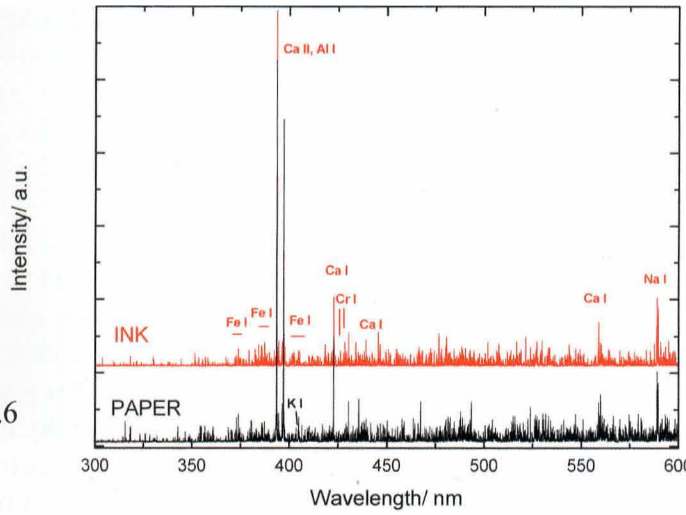


Fig. 1.6

contained names of dignitaries, who were already deceased at the time of its making. Close inspection of the text revealed that the names of three Austrian emperors appeared, i.e. *Iosif, Leopold, Frant*. As they were probably successors, they were Joseph II (1741-1790), Leopold II (1747-1792), Francisc II (1768-1835), while the successor Ferdinand I (1793-1875) was not mentioned. This means that the document was

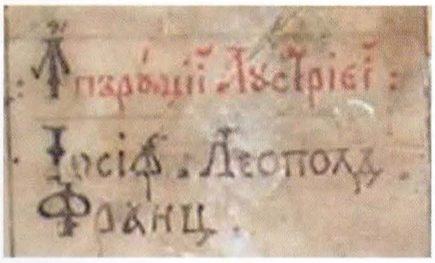


Fig. 1.7 Names of Austrian emperors mentioned in the *Obituary*

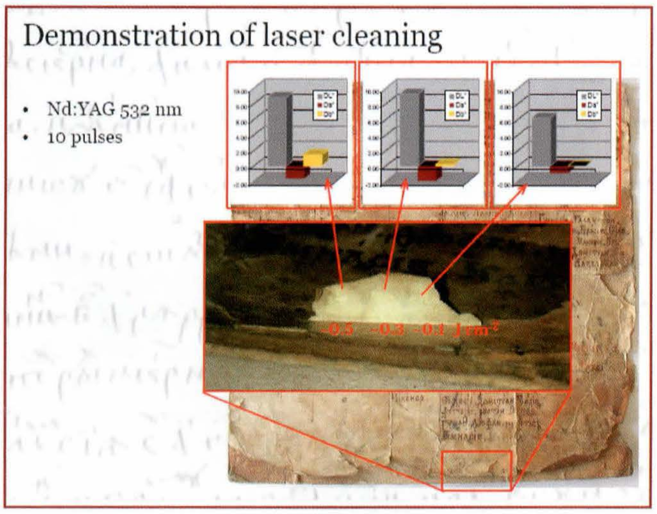
probably produced before 1875. In conclusion, the document was produced between 1850 and 1875.

Metal Cross

- The cross is made from common metal – 18th century;

Provenience: Banesti Parish church, Suceava

Fig. 1.8



Sp1	Sp2	Sp3
Cu	Cu	Cu
Ag	Ag	Ag
Ca	Ca	Ca
Na	Na	Na
	Au	Au
		Ni
		S

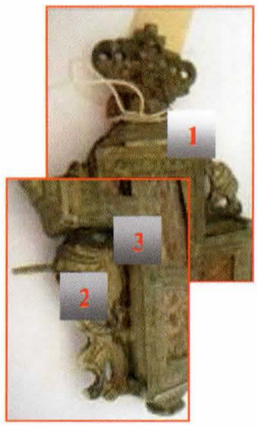


Fig. 1.9

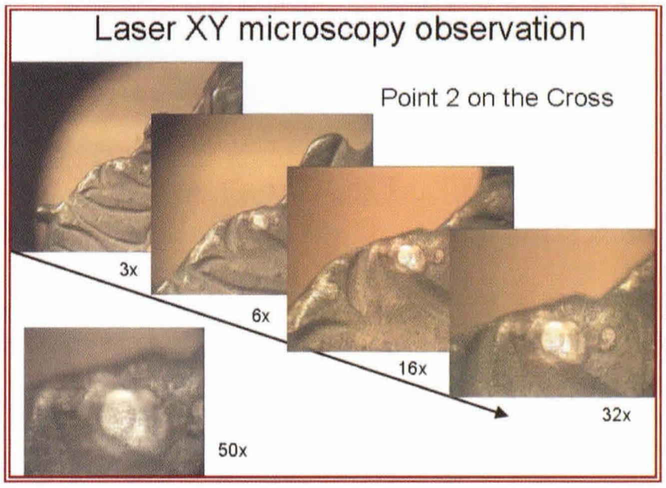


Fig. 1.10

Cash Pot

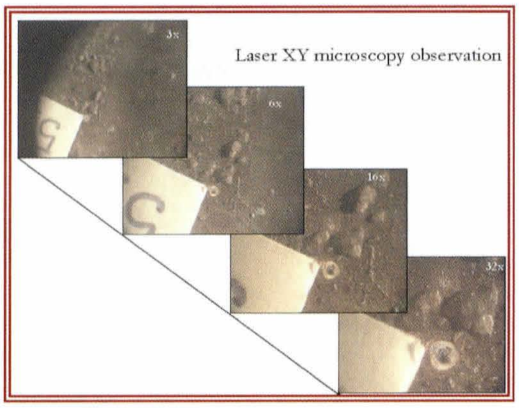
- Metal boll – yellow copper

Provenience: Zvoristea Parish church, Suceava

Example of multispectral imaging applied on valuable artwork objects from Sucevita Monastery :
Multispectral image analysis is a technique based on simple principles. Considering the observation that different materials absorb the light in different way, it is possible to measure the amount of light absorbed and reflected and to establish precise spectra of

Fig. 1.11

Fig. 1.12



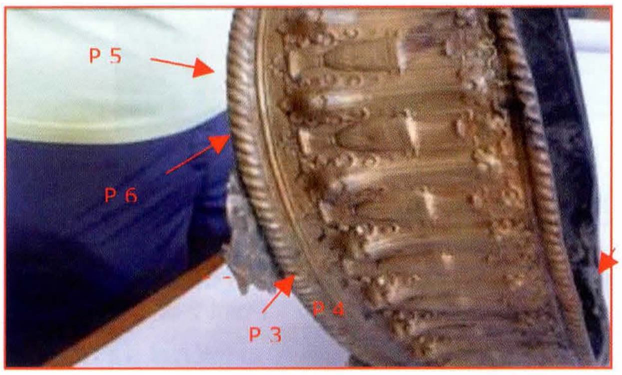
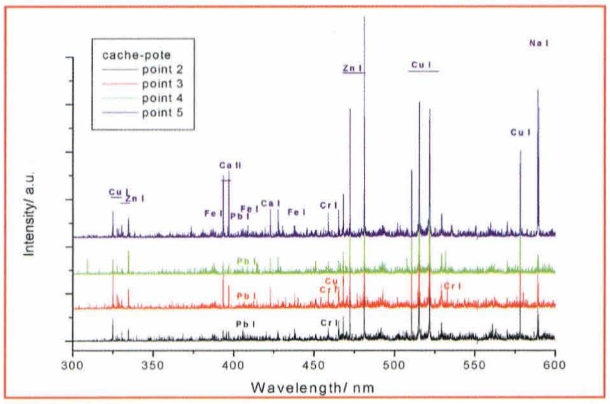


Fig. 1.13

Fig.1.14



absorbance or of reflection for substances that compose art objects. It is also possible to record these spectra not for visible waves, but also for UV and NIR waves. Approaching this idea from a different angle we can consider that electromagnetic waves from UV range to NIR range, including of course visible spectra, go through artwork materials in different ways. If it is possible to analyze the way that materials behave at electromagnetic radiation exposure with a handy mobile device a lot of valuable data will be available to art evaluation, conservation or restoration specialists without support from specialized laboratories.

Such device consists in a high resolution digital camera which can record in separate modes images in UV, visible and NIR spectra. These images are processed, compared and stored using dedicated software. Certain databases offer electronic version of classic conservation-restoration documentation.

Another aspect regarding artwork materials behavior at different ranges o UV-VIS-NIR spectra is related to identification of differences between almost the same colored materials. If the most trained human eye can hardly see any difference between two materials and these materials are chemically different somewhere from UV spectra to NIR spectra these materials will look different on computer screen due to selective mode operation of digital camera. Varying dependant on working mode selection it is possible to identify a complex range of degradations and modifications that art work materials suffered in time. During scientific investigations activities at Sucevita Monastery different sorts of art objects were investigated with this technique. In the following lines we shall present a part of the results which were used next to other analyzing techniques for a proper characterization of artifacts conservation status.

STOLE:

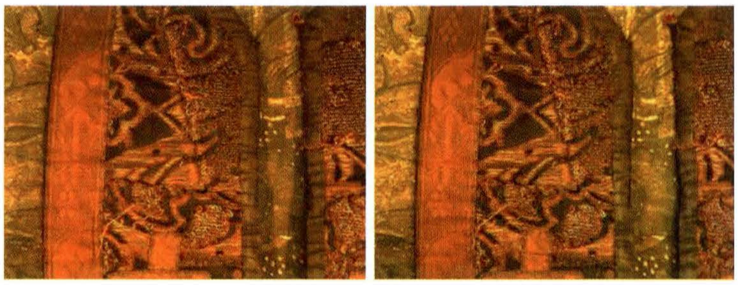


Fig. 1.15. Visible color image (left) compared with fluorescent UV illuminated image (right) showing no difference. The investigation in UV light is usually employed to detect microorganisms' presence on the surface of the art objects. In this case there were no detectable signs of fluorescence fact that proves the good conservation status of the object.

Fig, 1.16a

Fig. 1.16b

Fig. 1.17. Color visible image (up), false colored NIR image (middle) and UV image (down) indicating the areas where laser cleaning was tested in green (532nm) wavelength. The UV image proves that the surface of original material is not damaged by the laser beam.

3D laser scanning

3D scanning offers a three-dimensional image of the scanned object(s). The 3D scanner (optical surface digitizer) used is Surphaser 25HS is a 3D scanner that uses laser technology to produce high-resolution geometric models of three-dimensional objects. This scanner combines high accuracy with top performance, and is suitable for a large variety of applications, ranging from reproducing art objects for museum catalogs to reverse - engineering and product inspection for quality control 360° - 270° purposes.

This Hemispherical scanner is with field of view an is

Fig. 1. 18. Commanding the scanner with a laptop (the workshop at Balinesti Church)

commanded by an notebook or desktop PC.

The accuracy of the scan depends on many factors, for example, the environment conditions, temperature variation in electronic circuits that can result in changes in scanner parameters, specific properties of the object's surface, lighting conditions etc. The processing software uses sophisticated correction methods to minimize the accuracy loss, methods known as filters.

The scanner use a laser radiation, with 690 nm wavelength (red), continum wave, with 15 mW power (less then 100 part then power an usual bulb). Range of the scanner is between 1.5 m and 22m. Laser spot size at 10 meters is 5 mm and at 20m is 10 mm. Depending by the variance of relief and interest to capture the finest details, the resolution it may be modify from 17 up to 180 lines per grade (this correspond a distance between two near details by 170 microm, and the distance scanner and object 1.5m.

By scanning the object repeatedly from different angles and by software merging, it cans registry two (or more) different scans to obtain a 3D image, and we obtained a 3D construction with high resolution and without shadows (**Fig. 1.19**).

For combining two (or more) different scans the files must have common points, to identify 3 different details. The final file is called *project* and the scans are named *subprojects*.

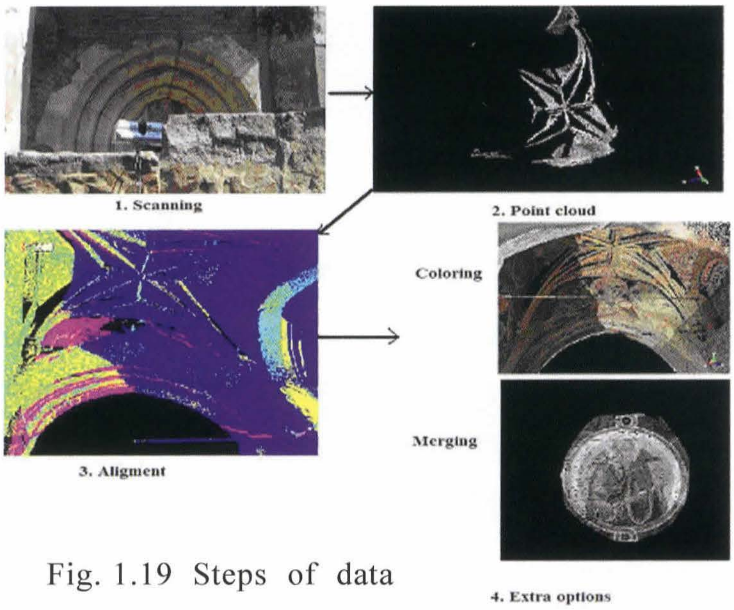


Fig. 1.19 Steps of data

One of the scanner advantages is its handiness: the physical dimensions and weight: 510 mm L x 170 mm W x 285 mm H, Weight 11 kg.

Fig. 1.20 Scanner situated on a tripod (the workshop at Balinesti Church)

The 3D scanning at *Sucevita* was based by digital reconstruction of the narthex *iconostasis* and funeral

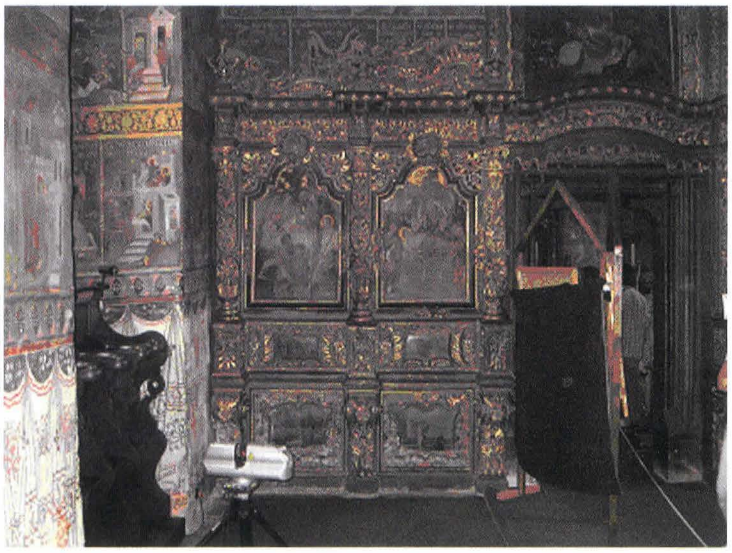


Fig. 2.1 Scanning the narthex iconostasis (Sucevita Monastery)

tombstones. Because of the variety of the relief, the 3D scanning of the iconostasis need different reposition of the scanner. It takes 4 scans of every half part and then one scan on top of the entrance in the Church. It needed 9 different scans that were over 20 GB of data. The resolution used was 40 lines per degree (approximately 0.6 mm) (**Fig. 2.1**).

The work at *Balinesti* Church was divided by two:

a) Scanning of *Dedicatory inscription*

The first scan was with 65 lines per degree resolution,

Fig 2.2 Scanning of *inscription*, on site arrangement

with the scanner at 5m distance from the *inscription*. This resolution was chosen because the inscription it's about

Fig 2.3 Scanner situated on a scaffold

4.5m above the ground. After the first results came over, there were a lot of areas shadowed so the scanner was apply on a scaffold so the scanner were perpendicular on the face on the inscription, at the distance of 2m. The resolution was 160 lines per degree and the final result was represented by 45 mil points (**Fig. 2.3**).

This porch is one of the most famous of Romania's Churches, the final result needed to capture all the details and all the faces of the stoop. For this there were 5 different scans, 3 scans that capture 3 faces of the porch and 2 scans of the interior of the porch, to see the details with no shadows.

Fig 2.4 Scanning the interior of the porch

Post processing time is equal with the time for scanning (maximum 2 hours/scanning), but for proper uploading time, it can be working with smaller project, or just with some details. Here there are some details from *Sucevita's iconostasis* (**Fig. 3.1**).

The software used for processing can display the results bought by mesh or by points and it can load a 2D image to obtain the colors of the scanned object (it may colors points and mesh). On the left part of the iconostasis it was a cutting out and with the software it was measured the

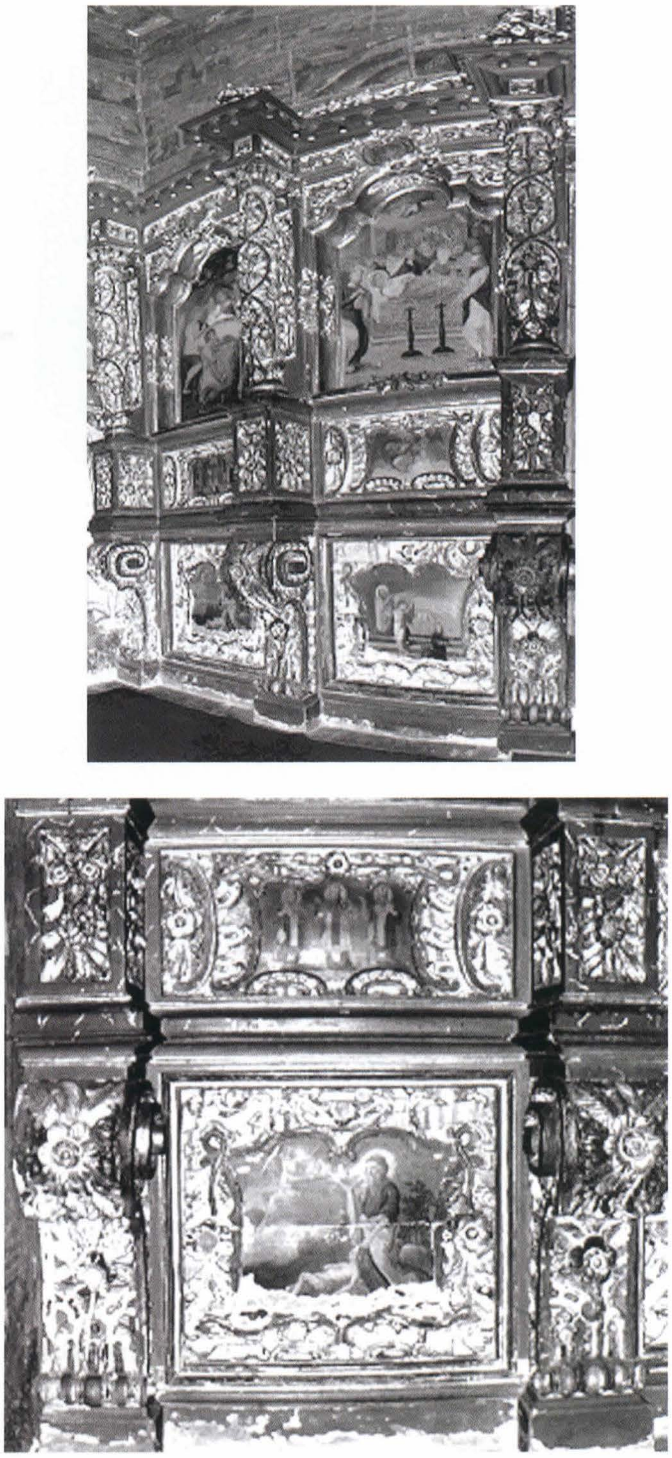


Fig 3.1 Different captures of some details

slit (**Fig. 3.2 a, b, c**).

Fig. 3.2 a

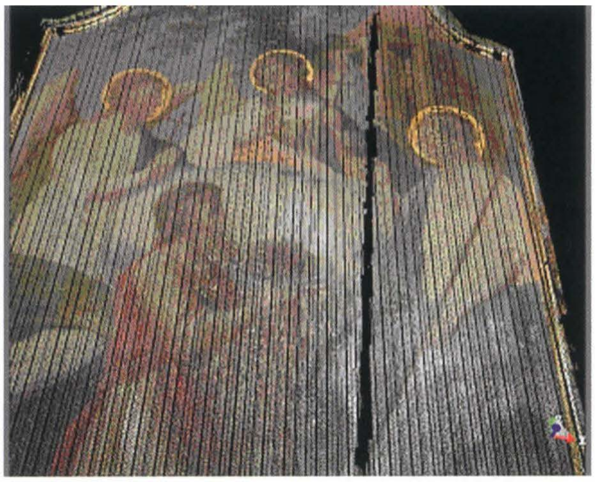


Fig. 3.2 b

Fig. 3.2 c

Fig 3.2. Same details represented by: a) points; b) colored points and c) mesh. The slit distance variable from 0.8 up to 2.3 mm

The image bellow in made from 46 mil points, contains 5 different files and the software may represent an image with the intensity of absorbed radiation **(Fig. 3.3 a, b, c)**

Fig. 3.3 a

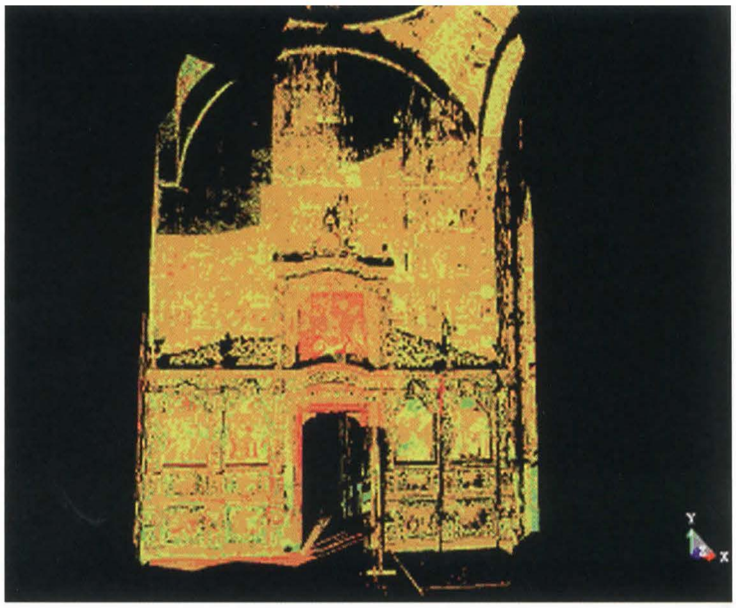


Fig. 3.3 b

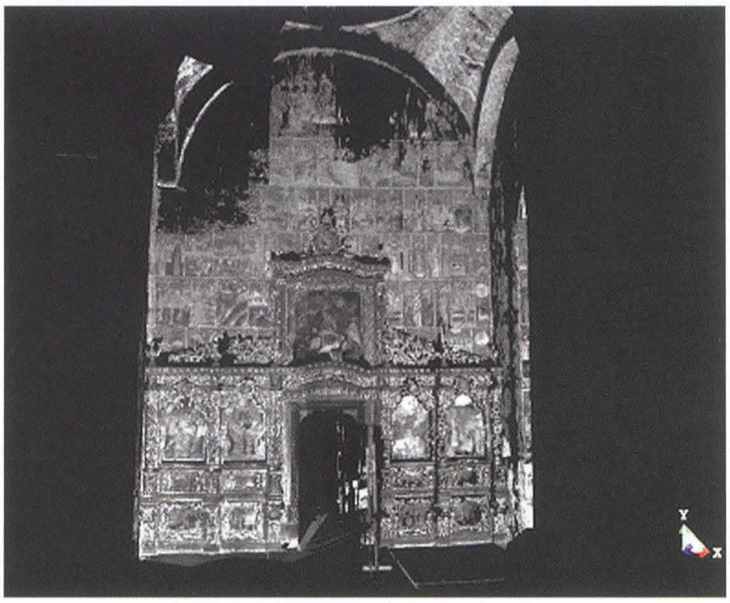


Fig. 3.3.c

Fig 3.3 The final result of iconostasis, represented by a) up-load files; b) intensity of absorbed radiation and c) in grey scale.

With software aid it can measure distance between points or details, which can determine profile of a letter from tombstone (**Fig. 3.4 a, b, c**).
The advantage of mesh representation is that the detail

Fig. 3.4 a

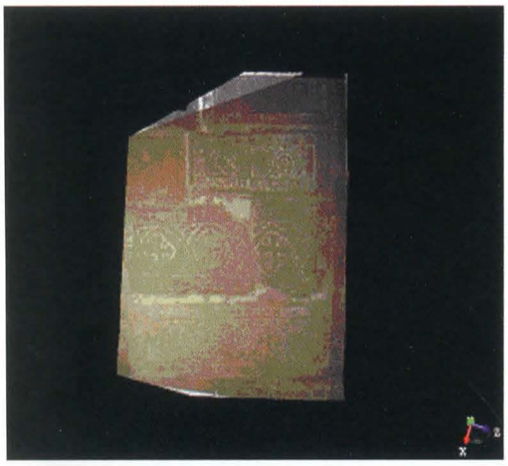


Fig. 3.4 b

Fig. 3.4 c

Fig 3.4 Different capture of tomb scans: a) grey scale points; b) colored points; c) letter profile

is observe better than by points representation, but is harden to work with this kind of files, because ask for more resource from the computer. In *Balinesti's inscription* this kind on representation is better then points representation because the writing were scanned only from front and from bellow, so the up side of the letters wooden be scanned, but the software used can interpolate that part using same representation like the bellow part of the letters (**Fig. 3.5 a, b, c**).

And the resolution of mesh is better then the point's representation, but the points represent the true information meanwhile mesh contains interpolation data (**Fig. 3.6 a, b**).
Representation of the porch was made by 56 mil points,

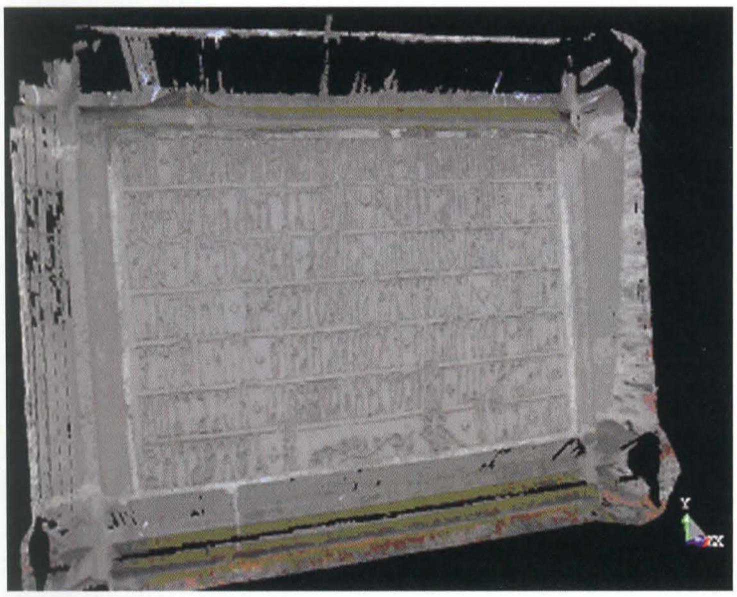


Fig. 3.5 a

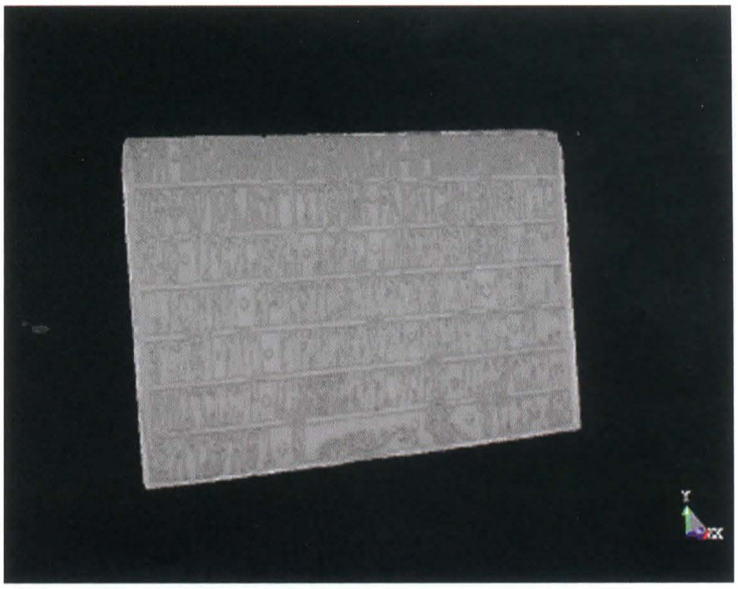


Fig. 3.5 b

Fig. 3.5 c

medium resolution were 0.9 mm and was made by 4

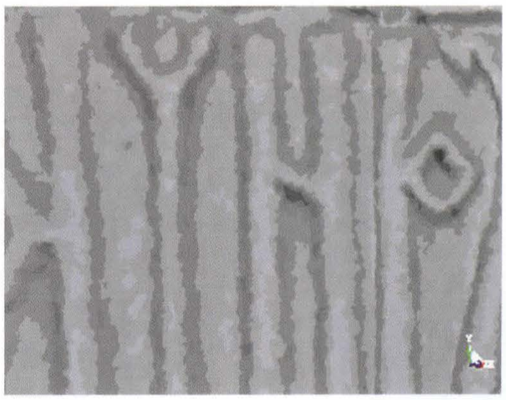


Fig. 3.5 d

Fig 3.5 Inscription represented by: a) color cloud points; b) mesh and a zoom on mesh c) and d).

different scans. The motive of this small resolution is that the interest of this project was to obtain fewer shadowed zones (**Fig. 3.7 a, b, c, d, e**).

Fig. 3. 6 a

Fig. 3. 6 b

Fig 3.6 Resolution of: a) points and b) mesh. The maximal rezolution by points representation is 170 microm and by mesh 100 microm.

By 3D scanning it may obtain high resolution computer model of the scanned object. Laser scanning should not be regarded solely as the means of recording, but it should be widely applied to the development of 3D digital archives. Laser scanning will not only bring efficiency to

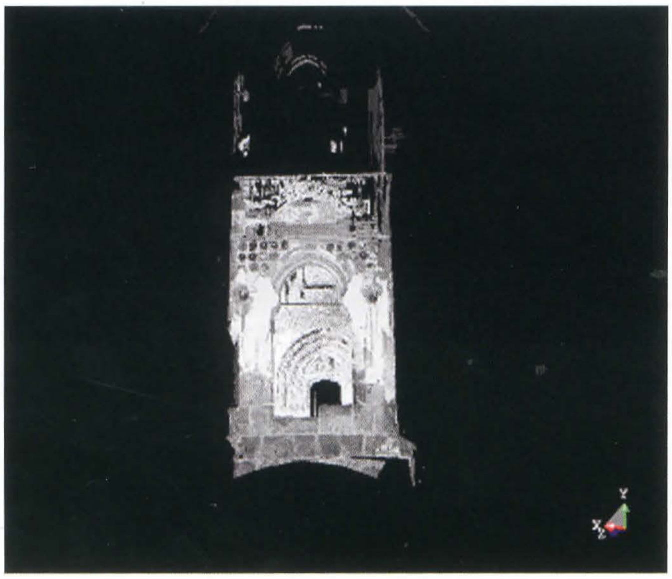


Fig. 3.7 a

Fig. 3.7 b

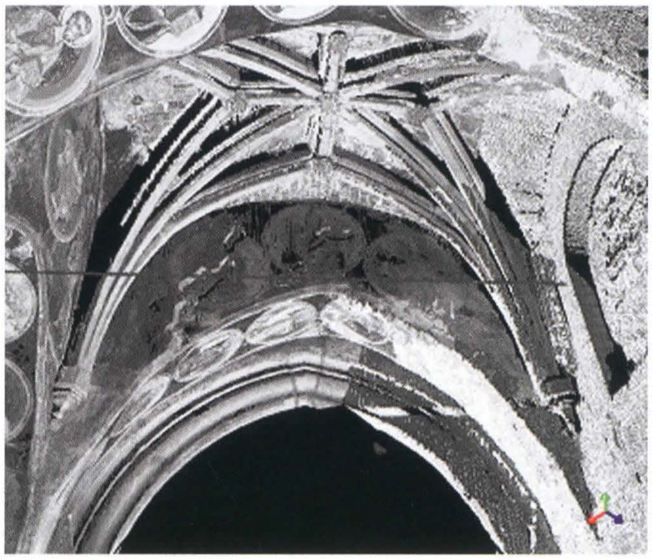


Fig. 3.7 c

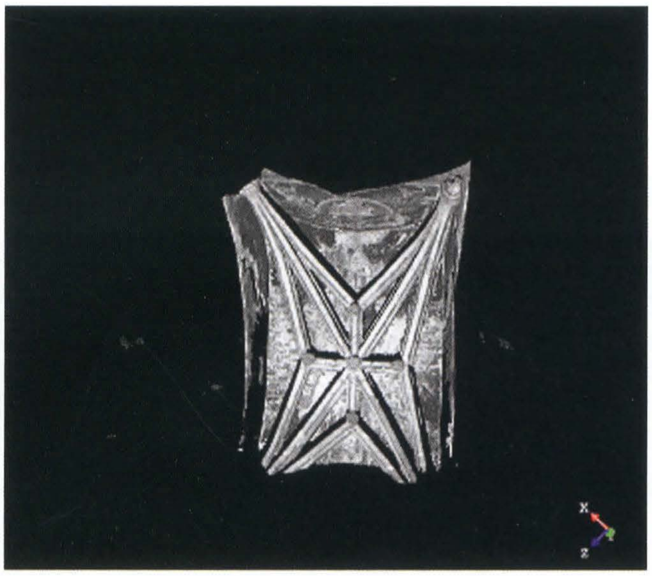


Fig. 3.7 d

conventional works such as making drawings and analyses of structures, but also make the management of whole attribute information such as components, breakage parts and repair parts possible. Moreover, the laser scanning technology indicates various future

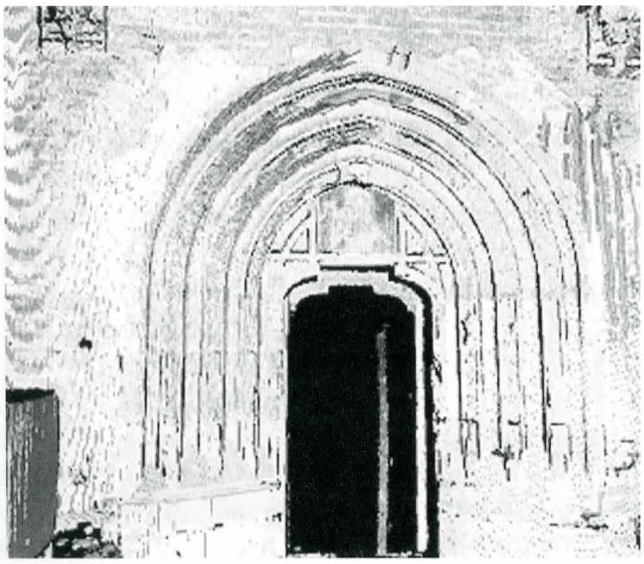


Fig. 3.7 e

Fig 3.7. Different detail of porch's scan

possibilities in the conservation of historic buildings. The simulation of restoration using 3D data obtained by laser scanning will greatly advance the ways of restoration from conventional ones like models and perspective drawings. It will also provide a great visualization method when it is applied to virtual reality that can offer real-time change of views and free movement.

In the exploitation phase of R&D projects and after the phase of the achievement of scientific results and the availability of demonstrators, a well funded strategy we proposed and direct collaboration are established for finding a continuity, with validation trials and technology transfer to end-users.

In this respect, we create a strong collaboration with Prof. Oliviu Boldura from CERECS ART S.R.L, for a long term monitoring of the various stress effects on monuments and for data interpretation, for creation of an advanced workshop hosting good-practice demonstrations.

Today the general acceptance of these physical methods is well acquainted in most of the conservation institutions, universities and research centers.

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