OPEN ACCESS PLATFORM FOR IN SITU CAMPAIGNS. CASE STUDY FOR MARTYRS' MONUMENT FROM MOISEI, MARAMURES, ROMÂNIA

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The current paper presents the results obtained during the first application of an original platform that grants real-time access to a variety of users to in situ studies and campaigns, opening an online door-way for national and international cooperation. The techniques selected for the investigation and cleaning of the monument - target of the study case, accessed through the online platform, were laser cleaning, LIBS, thermography, colorimetry and microclimate monitoring.

Keywords: online platform, laser cleaning, stone.

1. Introduction

Once with the start of the industrial era, scientists and engineers tried to obtain the maximum benefit from the possibilities the machines offered. A certain advantage of the machines was their immunity to hazardous environments. This advantage was first exploited in 1945 by Raymond Goertz who built a mechanical system that was remotely controlled by a human operator to manipulate radioactive material in a 'hot cell' from outside [1]. We can say that this was the first teleoperated system ever created.

Nowadays, the mechanical transmission of information has been replaced with electronic communication systems that are using wireless technology. Using the Internet or radio waves, now we can control from great distances any kind of device and see what we are doing by live video feedback. The most important applications of online teleoperation today are met in medicine, where we can operate high precision surgeries in real time, and in space exploration, where we have already three successful missions on Mars with teleoperated rovers.

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In the Conservation-Restoration field teleoperated investigations were first applied in 2011 in Romania, with a Laser Induced Fluorescence Scanning system (LIF) [2]. The LIF device is part of the ART4ART mobile laboratory [3], which was developed in 2008. The mobile laboratory is aimed for on-site campaigns that need more than one investigation to be done, spanning on several days or even weeks. It is modular, so it can be equipped in different configurations depending on the goal of the campaign: monitoring, investigation and/or intervention [4],[5]. More than that now the mobile laboratory is supported by a brand new online platform, which is actually a web based graphic interface and a database for the management of results, observations and access to live processes, for educational or research purposes. The core motivation for the development of the online platform stands in the fact that the result of the multi-disciplinary collaboration between archaeologists, restorers and scientific investigators (in spectroscopy, 3d laser scanning, LDV, GPR, microscopy and multispectral imaging, humidity and temperature monitoring etc.) are best processed and managed with IT tools coming from the computer science field (databases, human computer interaction science, communications/internet) [6]. Another aspect of this platform requires the association of the IT tools developed with the modern training strategy in accordance with all the legal aspects, ensured in the main project by a specialized private partner (coming from applied/educational sciences) [7].

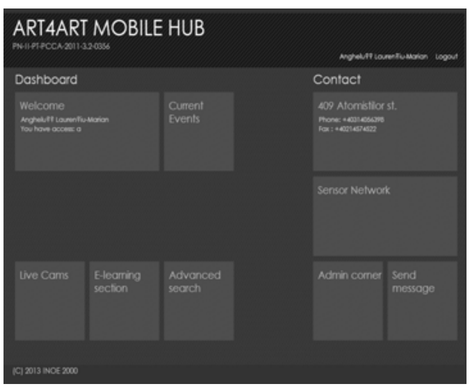


Fig.1. The control interface of the online platform

Fig.2. Real time images from Moisei Campaign

The first on site campaign sustained by the online platform was the restoration of the Martyrs' Monument from Moisei, Maramureş, Romania. The techniques selected for this campaign were: laser cleaning, LIBS, thermography, colorimetry, portable digital microscopy, photo documentation and microclimate monitoring.

2. Laser cleaning of the sculptured stone surfaces

The monument under investigation comprises 12 stone Figs.: 2 human faces and 10 traditional masks specific to Maramureş County, made by Vida Geza in memory of the martyrs of the massacre from Octomber 1944.

The sculpted figures are placed on 3 m height columns, arranged concentrically in a top of a small hill and were affected by a thick dark layer of adherent deposits and biological attack. After taking into consideration different types of cleaning tests (traditional and non-conventional) laser cleaning was selected for removal of the dark encrustation layer from the stone figures, so the ART4ART mobile laboratory was sent on the location of the restoration site. Double pulse LIBS analyses were made in order to determine the composition of the stone substrates, using the 1064 nm wavelength in *single pulse* regime. The delay of the spectrometer was set at 2 μs and the gatewidth at 10 μs.

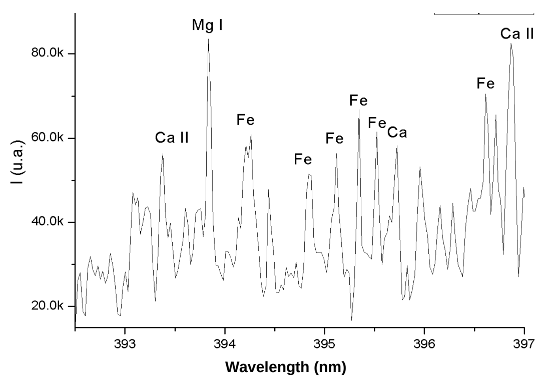


Fig.3. LIBS sp spectra, range selection: 393 -397 nm.

From the spectrum the following elements were identified: Ca, Fe and Mg, typical elements for travertine type of stone. In order to select the proper cleaning regime, several tests were carried out on travertine samples artificially soiled with candle smoke, using different laser energies: area 1 – 130 mJ, area 2 – 160 mJ, area 3 – 192 mJ, area 4 - 217 mJ and area 5 – 244 mJ.

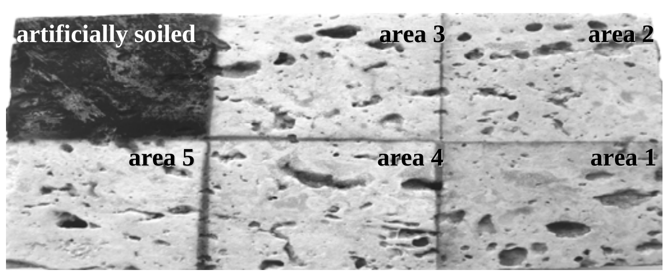


Fig.4. Photo of the laser cleaning stamps

The cleaning tests were evaluated using microscopic and colorimetric techniques, in order to select the working regime with high cleaning efficiency that does not induce any modifications to the stone substrate – morphologically or colorimetrically. In *Table 1* are presented the colorimetric parameters CIE

L*a*b* [8] recorded for the cleaning tests.

Table 1

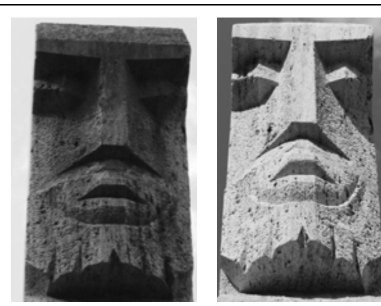
Evaluation of the color parameters

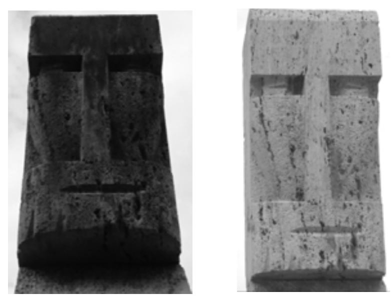
CIE L*a*b*	fresh sample	artif. soiled	area 1	area 2	area 3	area 4	area 5
L*	80.42	13.04	66.79	69.07	76.82	79.69	79.66
a*	0.95	0.26	1.36	1.46	0.99	1.03	1.18
b*	9.34	1.52	9.85	10.35	10.40	9.92	10.95
ΔL*		67.38	13.63	11.35	3.6	0.73	0.76
Δa*		0.69	-0.41	-0.51	-0.04	-0.08	-0.23
Δb*		7.82	-0.51	-1.01	-1.06	-0.58	-1.61

The evaluation of the laser cleaning tests resulted in the selection of the energy range that provided the best results for this type of travertine substrates: 200-250 mJ. Considering these data, the laser cleaning of the Martyrs' Monument from Moisei had commenced.

In *Table 2* there are described the laser cleaning parameters used for each of the statues, grouped accordingly to the thickness of the adherent deposit layer, as well as the degradation of the stone surface.

Table 2

Statues 1 & 12 A = 1.74 m^2 adherent deposits layer: moderate stone surface condition: severly erroded E = 215 mJ	 statue 1: *before* *during* *after*
Statues 2, 4, 5, 9, 11 A = 4.35 m^2 adherent deposits layer: moderate stone surface condition: good E = 215 mJ	statue 4: *before*  *after*

Statues 6 & 10 A = 1.75 m^2 adherent deposits layer: thick stone surface condition: moderately erroded, not uniform E = 215 mJ	statue 6: *before*  *after*
Statues 3, 7 & 8 A = 2.61 m^2 adherent deposits layer: thick stone surface condition: moderatly erroded E = 215 mJ	statue 7: *before*  *after*

The laser cleaning of the stone figures was monitored using thermography, digital microscopy and colorimetry, in order to have real-time control of the cleaning procedure, as well as to collect reliable data that confirm its non-invasiveness to the stone surface.

Thermography was used in order to monitor the temperatures reached by the surface during the laser cleaning. Laser cleaning process is based on ablation of the layer of adherent deposits by selective vaporization: the impurity layyer reaches its vaporization temperature while the stone substrate is kept on a low temperature range that does not induce any modifiations. In order to protect even more the stone substrate, a thin pelicula of water was applied on the impurity layer just before its ablation, fact that basically shielded the stone surface.

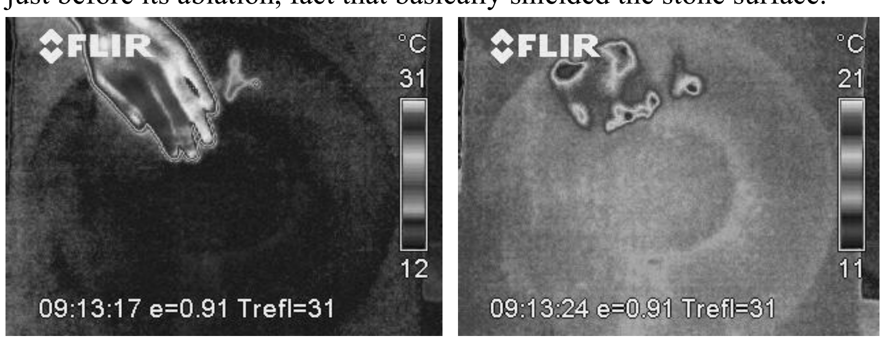


Fig.5. Thermal images: temperatures reached and thermal relaxation time

As we can see from the thermal images, the temperatures reached by the statues' surface during the laser cleaning process are in the range of 18-22 °C, clearly lower than the ones induced by the sun in a warm sunny day. The thermal relaxation duration is a few seconds, similar to the one after removing a warm hand from the stone surface.

3. Microclimate monitoring

In the time frame of 23 - 27 August 2013 the temperature and the relative humidity of the atmosphere at the working site level were recorded using wireless detection sensors.

Two sensors and the reception unit (that also has a detection sensor) were placed on the scaffolds of the statues at different height levels: on the ground, on top of the statue and at the working level in order to record a complete monitoring map.

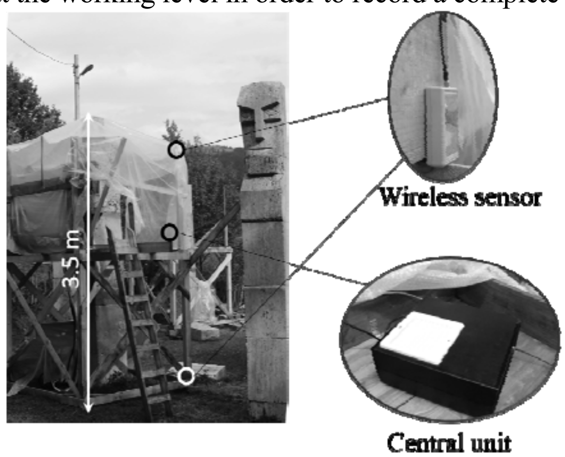


Fig.6. Sensors' positioning

The remote sensors were transmitting data on every 15 minutes, while the central unit recorded data on every 5 minutes.

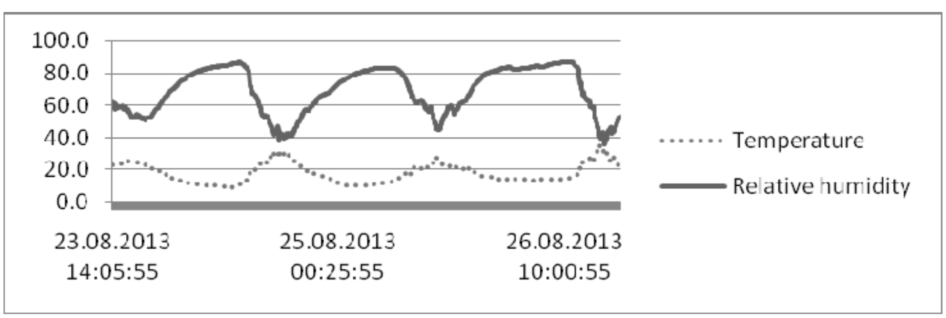
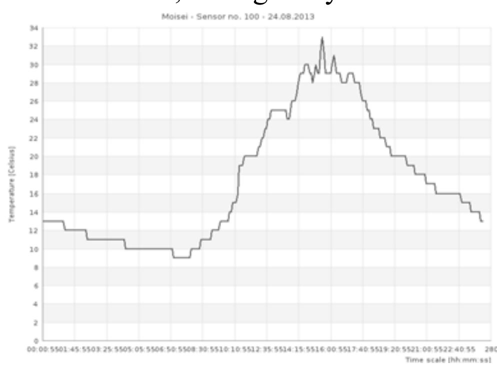


Fig.7. Temperature and Relative Humidity evolution during 4 days

In the two figures below the temperature and the relative humidity evolution in time, during a day can be observed.



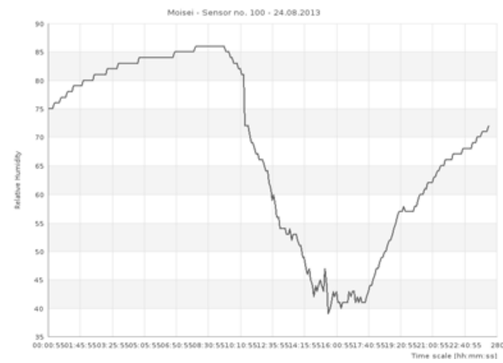


Fig.8. Temperature data

Fig.9. Relative humidity data

As seen in the table below, there is a 22.3˚C temperature difference between the minimum and maximum values (12.8˚C – 35.1˚C), between 07:00 AM and 16:00 PM. The relative humidity is at maximum when the temperature is at the minimum, decreasing until 16:00 PM when the temperature has reached its maximum. These readings are similar for all four days of recording, in different areas.

Table 3

Minimum and maximum values for T and RH recordings

Day	T [°C]		RH [%]
Day 1	min	9.1	50.8
	max	26.1	86.3
	Δ	17	35.5
Day 3	min	13.3	44.7
	max	28.4	86.6
	Δ	15.1	41.9

Day	T [°C]		RH [%]
Day 2	min	10.3	38.5
	max	32.5	83
	Δ	22.2	44.5
Day 4	min	12.8	36.1
	max	35.1	87.4
	Δ	22.3	51.3

Minimum temperature recorded during these four days was 9.1˚C with a relative humidity of 50.8% while the maximum temperature recorded was 35.1˚C with a relative humidity of 87.4%.

4. Conclusions

The online platform offers a low cost, spirited manner of access on different user levels that eases the national and international multidisciplinary collaborations, the know-how transfer, making available a strong modern tool of learning in the same time.

The techniques necessary for the preliminary investigations, as well as the ones linked to laser cleaning monitoring were selected and accessed using the online platform. All the operations have been recorded in the campaign's specific database and the field activities were supervised and observed in real time via the IP cameras.

The laser cleaning of the thick black crust that affected the stone surface was performed after assessing the conservation state for each of the column using portable non-invasive methods such as digital microscopy and colorimetry. The laser cleaning temperature path was observed in real time using thermography in order to make sure that whilst the adherent deposit layer reaches its vaporization temperature, the stone substrate remains in a safe temperature area.

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