This paper describes an online instrument with multiple purposes developed to complement the functionality of a mobile laboratory employed in the field of Conservation – Restoration of Cultural Heritage. The instrument was developed as a web-based platform using common web design technologies. The platform can be used for the online access to infrastructure of the mobile research laboratory like real-time monitoring, teleoperation of certain devices, results and reports database or real-time communication with remote researchers regarding specific investigation tasks on field. It is also the base support for specialized online courses, tutorials and demonstrations for students coming from archaeology, art conservation studies or technical fields.

Key words: teleoperation, remote control, e-infrastructure, e-laboratory, database, online courses, archaeology, artwork conservation-restoration.

1. INTRODUCTION

Modern technology and the widespread use of computers and high speed communication protocols enabled the scientific community to greatly improve the accessibility to research laboratories’ infrastructure. Employing technologies like teleoperation or remote control, real-time monitoring of processes and relational databases for data management of a research laboratory can easily lead to the possibility of the working specialists to share their discoveries and working methodologies with other fellow scientist or the students before the beginning of their scientific careers. These modern instruments are also used to complement e-learning activities by allowing remote students or experts to be able to see at work specific installations and even actively participating in experiments remotely in real-time.

This kind of distance learning is a great improvement if we look back at the first attempts in the eighteenth century when Caleb Phillips was promoting in the newspapers his weekly mailed lessons [1]. Today, online courses, virtual labs and webinars are accessible to anyone with an internet connection. Distance education now is not consisted only by electronic books, tutorials or other recorded materials (asynchronous learning).
Today it is possible to access in real time an online class held by a real person who shares his knowledge at the same time with students located in different cities or countries (synchronous learning). A wide range of technologies and tools are available for synchronous learning like the telephone, TV education shows and web conferences (with video and VoIP support) [2]. Once with the spread of ICT, e-learning has become the main method of distance learning. E-learning is based on the use of many types of media that deliver information and knowledge as text, audio, video, images, generated animations, virtual three dimensional worlds [3]. This kind of approach can extend any research group’s visibility and its quality validation within the scientific community.

In this paper it is described such an effort to upgrade a modern mobile research laboratory employed in the field of Conservation-Restoration of artworks and monuments in the Cultural Heritage, also known as the ART4ART mobile laboratory, developed by the National Institute of Research and Development in Optoelectronics INOE 2000. This upgrade consists in developing a tool (online platform) that can link remote users and scientists to all of the mobile research laboratory devices, practices and knowledge. This instrument has already been tested in various ways: a field campaign for laser cleaning and monitoring in which all the processes undergone were supervised by specialists across over 500 km distance by IP cameras and the online platform real-time activity reports; teleoperation experiments since 2010 with the laser induced fluorescence scanning device in collaboration with national and international partners; online courses and tutorials for students abroad.

This platform is aimed at both experienced restorers or archaeologists and students coming from different disciplines like archaeology, conservation-restoration sciences, physics, chemistry, engineering and any other discipline related to the applying or studying modern methods of investigation and monitoring of artwork materials and their state of conservation. The platform was realized having a relational database at its core in order to a better and faster management of all experiment data, parameters used, object details, work conditions and other feedback. It is designed to help making the right decisions in key points of operations by delivering essential knowledge from past experiments in similar situations. Providing the database with large amounts of valid data on each experiment improves the quality of the service offered in the future.

1.1. RESEARCH MOBILE LABORATORY INFRASTRUCTURE

In order to understand the functionality of the platform, it is important to know the structure and the specific of the mobile research laboratory. It is the central piece during field campaigns whether they are aimed for intervention, investigation, monitoring or altogether [4]. The power autonomy, supplied by the power generator, for all the connected equipment is extremely important in
archaeological sites where there is no electricity. Depending on the campaigns’ specific the mobile lab can be configured with different associations of equipment. The main devices are: cleaning lasers (up to two units), 3D laser scanner, Doppler Vibrometry scanning laser, thermal camera, multispectral camera, ground penetrating RADAR, micro-climate wireless sensor network (long term monitoring of relative humidity, temperature and air pollutants), portable digital microscope, portable colorimeter, LIBS and LIF investigations setups, photo/video cameras and several IP cameras. Other complementary instruments can be added as well.

Until the recent upgrades, which are discussed in this paper, the deployed setup served as a stand-alone workshop on a field site for research activities, studies or intervention. Experts or students could visit, learn and interact with the scientific crew of the mobile research laboratory on site, being able to see first-hand the operation of modern technology used Conservation-Restoration.

2. NETWORK DESIGN AND DATABASE STRUCTURE

The new added features, described in the first part of paper, required several mandatory modifications in the logical and physical configuration of the mobile laboratory. First of all there was needed for a reliable independent Internet source and a solid and secure network design for all the computers attached to the different devices.

The Internet provider had to have a national coverage especially in the remote areas where there was no local Internet provider, so the best option was to contract a national mobile communication network company. The Internet connection is ensured by a local modem with a static IP address that is configured to route external access to any of the network connected devices. An optional omnidirectional antenna is also available for signal enhancing in remote areas with weak signal.

The local area network is based on wireless technology. On a field working site, one of the important factors of the efficient use of the investigation devices (and their attached computers) is their mobility and commodity. The computers (with wireless adapters), notebooks and mobile devices can access from any signal covered area the online platform to gather/send data necessary for the investigation. Another factor is the scalability. As the investigation complexity grows, the network must be extended in short time. Usually, the wireless networks can be extended instantly without other cables or hardware complications. From the costs point of view, the wireless LAN reduces or even eliminates the costs for moving, reconfiguring or its extension with new devices.

The online platform for the resource management and control in the mobile research laboratory was designed as a website and is currently stored and managed on the INOE 2000 public server. All the data, files and usage statistics are stored
using a relational database managing system. A relational database is an organized structure of tables (relations) together with the links between them [5]. Fields and records are represented by table columns and rows. A typical database can have between 10 or 1,000 tables. Each table contains column that other tables can link in order to obtain information about that table. Based on this concept there can be created many such small tables with their sole function to make easier links between data tables.

2.1. TWO-LEVEL ARCHITECTURE VS. THREE-LEVEL ARCHITECTURE

The initial plan was to design the online platform using client-server architecture (two levels) as described in Figure 1. A software application that would ensure the input and the return of information to and from a database would represent the online platform. The software application and the graphic user interface would have been stored on the client computers while the database was stored on the local server of the mobile research laboratory that could be accessed via the Internet or LAN by remote users.

Fig. 1 – Two-level architecture.

The advantage of a two level architecture was the ease of understanding of the system resulting in an easier management. The problems appear when more users are connected at the same time, considerably limiting the capability and the performance of the system. In this case an even bigger issue was the fact that the platform and all its data were available only when the local server of the mobile lab...
was online. These inconveniences for the main purpose of the platform led us to have a different approach on the system architecture.

In the three-level architecture the main difference is the fact that both the software application and the database with all the result files are stored on a public server with a permanent online access. Today this architecture is the main concept of web design. Therefore the platform software application was designed as a website that can be easily accessed using a web browser, from any computer with an Internet connection. The three levels of this type of architecture are: the presentation level, the processing level and the data access level.

- Presentation level is the first level of the application and represents the user interface. This level transposes the tasks and results to be easy to understand by the user. The end-users should be able to interact with the database without the help of IT experts [6]. This is achieved by using a web server that can deliver static or dynamic contents that are interpreted by a web browser for the end-user.

- Processing level is the second level and it coordinates the application, process commands, makes decisions and logical evaluations and mathematical operations. It also links the adjacent levels. It usually implemented by employing an application server for the processing and the generation of dynamic content. There is a wide range of such application servers: ASP.NET, PHP, JAVA EE, and others.

- In the Data access level information is stored and accessed in a database of a file system. This information is then send to the second level to be processed and then, if needed, to the first level to the user. It is represented by a database management system (DBMS) that comprises both the database and the management software allowing the administration and access to information.

Following this architecture for the purpose of this application, the website with the graphic user interface is hosted on an online server with public access. The users/clients accessing the platform won’t need any application installed on their own PCs. Both casual users inspecting the data on the platform and the operators inputting data in the database are using the same interface in a web browser having only different access authorization, as it will be described later. This way the access is more easy and intuitive than in the two-level architecture. More than that, the new intermediary processing level and the separation of the database level from the dynamic operations level facilitates the administration and the future improvements that could be made to the application (e.g. change of database system, transfer from a graphic interface to another etc.).

2.2. ONLINE PLATFORM SECURITY

The security of the platform website is based on authentication and authorization. Authentication is made with a password corresponding to a username. The user data (access level, general information) are stored in the online
platform database. Authorization is the process that allows the users to access certain sections of the online platform. The access policy has three levels of access: administrator, operator, and guest.

![Authentication and authorization process](image)

As seen in Fig. 2, the Guest users are allowed to access some sections of the website (e-learning section, IP cameras, teleoperation sessions and other general information). The Operator user is allowed to consult, modify, and add data in the ongoing events and experiments database. The Administrator user has access to all the fields and tables of the database. He can manage the users’ tables in the database and correct any errors in the database that the operator users are not allowed to do. Each page of the platform website checks the authorization of the logged user before displaying its contents. Some functions and operation on a general access page can be restricted to general use, in this case a message window pops up with an *Access restricted for your authorization level*.

### 2.3. DATABASE STRUCTURE

The DBMS used in the data access level is MySQL while the processing is realized with the programming language PHP. The platform database is structured in 20 tables.

The table personal holds the information about all the registered users and their security permission levels. As mentioned before, a guest user has access to a limited number of sections of the web platform. The operator user can create and manage events as they are developing in time on field as follows. If the event does not exist the operator creates a new one filling in a form with general information about the specific of that event: name, small description, duration and which project is financing it. During an event there can take place many operations on different locations. The operator(s) must define each location individually with codenames representing that workplace or sector (*e.g.* church nave, tower). The location may be a section of a building or a working area in a much larger site. This
location is described by a codename, detailed description, set of images and optionally a link with the exact location on Google Maps™. The field event_id is the linking relation with the unique event table. Further on, each location is divided into investigation areas. These areas represent the subject surfaces or artworks on which there can be made investigations. Each investigation or operation made on a specific investigation area is recorded in the investigation_list table with all their details. If the investigation area has an IP camera available, it is also specified in the description so that the platform could link the authorized users to the live camera address for real time monitoring purposes. At least one operator must be assigned to each recorded investigation or operation. The operator must be registered in the database system. The event_operator table keeps the relationship between the personal and investigation_list tables. Linked with the investigation_list table there are several other tables that are detailing certain fields of information (application, equipment_id) while others are directly linked to the unique id of each recorded investigation (results, complementary_analysis). Each investigation can have more results attached as well as complementary investigations, that are referring to methods or techniques that are not included in the mobile research laboratory.

Fig. 3 – Main tables of the database and their relationships.
For each investigation, the equipment is selected from a drop-down list of devices codenames. These devices are defined and stored in the database having a modular structure in order to be possible the completion of the list with other new devices anytime.

As seen in Fig. 4, there are four main techs representing the specific of the investigation/operation devices: spectroscopy, laser, imaging and scanning. Some of the mobile research laboratory devices are designed with two or more of these techs in their structure. So this solution was chosen in order to be able to easily add new equipment that might not be categorized in only one type. For example the Laser Induced Fluorescence device has laser, spectrometer, scanning and even imaging capabilities. In order to record all the possible parameters and precision limits for all the devices the four-tech structure was the most agreeable.

2.4. GRAPHIC USER INTERFACE

The platform graphic interface is realized as a website that is currently hosted on a public server. During the designing processes where employed several programming languages like: HTML5, PHP (for database processing), MySQL (database interface) and CSS3 for visual styling. For ease of management there were designed special pages for each database table that allows the input, deletion or editing data. The visual design emulates the metro style interface that was created by Microsoft for the graphic interfaces of Windows 8™ or the XBOX gaming platforms operating systems. This type of graphic interface puts accent on a good visibility that emphasizes the functional elements of the interface and a less
importance on the visual aspect and design of the page. The page is accessible from a web browser that is compatible with most of the HTML5 functionality.

Fig. 5 – Online platform graphic user interface.

3. REMOTE CONTROL AND MONITORING

3.1. TELEOPERATION

The online platform offers access to the remote controlling or the teleoperation capabilities of certain devices within the mobile laboratory. Teleoperation is not a new concept. In 1898 Nikola Tesla patented a method for controlling a device without the limitations of wires, cables or other electrical connections. Back then he used the natural media (earth, water, air) for the transfer of electrical impulses needed for the desired actions of the mechanism. Today we have the Internet as the fastest media for data transfer over great distances. Applications in medicine, military and aerospace industries are using teleoperation methods to control unmanned vehicles or instruments in areas where human presence is not possible. Based on the same principles, in 2011, for the first time in the artwork Conservation-Restoration field, INOE 2000 has developed an investigation device using the laser induced fluorescence spectroscopy (LIF) that was adapted to be operated via the Internet, thus allowing studies to be made without the need of an expert in situ [7]. This is a great asset especially on sites where a specialist cannot be present or the calendar schedule of the archaeological site where the device is deployed cannot allow human presence due to site protection rules or the harsh environment. Once the LIF investigation device was easily accessible by teleoperation from any point in the world it was also used in
educational purposes. Students from partner universities (Fayoum University in Egypt, or University of Vienna – Physical Chemistry department) are already able to access and develop experiments from distance with real time feedback and results.

3.2. REAL-TIME MONITORING

In the concept of this platform there are two meanings for real-time monitoring. The first one refers to visual monitoring using the IP cameras. These proved to be useful for certain operations supervising from distance by experts or for educational purposes during online courses and demonstrations. A special section in the webpage is always updating with the latest data on the available IP cameras on field. The operators working in the designated areas with the IP cameras must provide within the platform database the camera accessible address.

The other meaning refers to long time monitoring of the microclimate of the working sites. There are currently three sensor networks available for long term monitoring, but only one can be remotely accessed through the online platform. The intelligent wireless sensor network central unit [8] can deliver results in different formats regarding the temperature, relative humidity and certain pollutants (H2S, SO2 and NO2). The central unit collects the data from the sensors and with the help of programmed scripts the data is loaded into the database. For each different monitoring location an operator must define in the platform the new location and then a new table is automatically created within the database. The data can be viewed as graphs by selecting in a drop down list the day desired, showing up to the last recorded values. This section is independent from the events section.

3.3. CORRELATION OF ASSOCIATED INVESTIGATION RESULTS

The investigation devices that are part of the mobile research laboratory are delivering results in different formats, but most of them can deliver data as images representing specific characteristics of the investigated surface. In order to have a good idea about the conservation state of an artwork the more data you have the better. Having such a collection of different data types from different devices may be confusing for some investigators without a proper tool for associating them. Therefore, instead of looking at several distinct data images and a digital 3D model of an investigated area, we can have a unified complex digital model that contains all the available data of the studied surface [9]. In this respect it was developed a method of correlating all the imagistic data results over an artwork surface with its 3D digital representation [10]. The resulted models are accessible via the Internet.
in a virtual interactive environment that allows the viewer to study the investigated surface with all the needed data overlapped on the areas where they were collected.

![Online tool for visualizing 3D associated investigation data.](image)

Fig. 6 – Online tool for visualizing 3D associated investigation data.

So far this method has been applied during several mobile research laboratory field campaigns: painted underground tombs in Dobrudja (2\textsuperscript{nd}–6\textsuperscript{th} century A.D.), several churches of historical importance across Romania and an important Buddhist temple in Ladakh, Jammu & Kashmir, India [11]. This tool is now used during the e-learning sessions within the platform program as it will be described later.

3.4. E-LEARNING FEATURES

One of the main purposes of the online platform was to have a data center where experts and students can have access to the mobile laboratory infrastructure for research, investigation and study. A set of lab works and courses have also been elaborated for the purpose of the online platform e-learning section. These courses are intended to be transmitted in real time over the Internet from working sites to remote universities and specialized schools. Students can view the operators at work directly on site or in lab for sophisticated setups [12] with the internet accessible IP cameras installed in proximity. Also webinars are held using an online conference web based tool developed independent from the online platform. Offline content like presentations, documents, statistics, movie clips or 3D models with associated investigation data are available anytime in the e-learning section. For the real-time online webinars, workshops or presentations a schedule is established with the organizing institutions.
4. CONCLUSION AND DISCUSSIONS

The online platform has been successfully tested on several working sites like The National Open Air Village Museum Dimitrie Gusti in Bucharest (2012), Museum of National History and Archaeology in Constanța (2011) and The Martyr’s Monument in Moisei, Maramures (2013). Online courses, real-time demonstrations and teleoperation investigations have been held in collaboration with the Fayoum University in Egypt and University of Vienna.

As future work, the platform database and the 3D associated models could be further combined for a more complex tool of visualizing data. While the 3D model offers only visualization features, a more complex interface would allow the visual information to be accompanied with complete data from the database. That would be a more intuitive and fast way of displaying information regarding certain aspects of an artwork.

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