

## THE TELEOPERATION OF A LIF SCANNING DEVICE

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*In această lucrare este prezentată o platformă de teleoperare prin Internet pentru un dispozitiv de investigare a fluorescenței induse cu fascicul laser, utilizat în investigarea suprafețelor pictate ale operelor de artă. Partea hardware a sistemului este alcătuită din dispozitivul de investigare transportabil și un calculator personal utilizat ca și server și panou de control. Aplicația software utilizează arhitectura Client-Server pentru controlul dispozitivului și recepția informațiilor răspuns. Interfața cu utilizatorul este realizată cu ajutorul tehnologiei web-server a platformei LabView. Dispozitivul este operat de la orice distanță, în timp real, prin intermediul unei pagini web HTML.*

*In this paper it is introduced an internet-based teleoperation platform for a laser induced fluorescence device used in the investigation of the painted surfaces of artworks. The hardware of the system consists of a transportable laser scanning device and a personal computer used as server and service control panel. The software employs the client server architecture for device control and feedback data. The user interface is built for the purpose of interaction, using the LabView web-server technology. The device is operated from any distance, in real time, through a embedded HTML web page.*

**Keywords:** teleoperation, laser induced fluorescence, LIF, laser scan, real-time operation

### 1. Introduction

In this paper we present our work on the improvement of a laser induced fluorescence (LIF) scanning device, to extend its functionality and accessibility. The LIF scanning device is used in the artwork investigation field. Using a UV (@ 266 nm) pulsed laser beam, for material compound excitation, it can help the specialists in indentifying different types of pigments or microbiological attacks. With its 1,25  $\mu$ J per pulse energy, this device is a non-contact and non-destructive tool for investigation [1], therefore it is recommended for studying heritage artworks. This device also have ca capability of scanning entire areas, delivering results as intensity distribution maps for any material spectral characteristics [2].

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Being transportable and integrated in the complex mobile laboratory ART4ART [3] [4], it can be deployed on any site.

As for any investigation device, there is always a problem that cannot be easily solved. The specialist that needs the investigation data has to be on site, where the device and the artwork is situated. Another problem is the weather calendar of different archaeological sites. One solution to this problems is the teleoperation of the investigation devices.

Teleoperation could be defined as the continuous and direct control of a remote machine. Initially developed for manipulation of radioactive materials, teleoperation allows an operator to exercise force and accomplish movements through visual, resonant or tactile data.

The teleoperation is not a novel idea. Since 1898, Nikola Tesla has patented his “Method of and apparatus for controlling mechanism of moving vessels or vehicles” which was the first system of controlling a device without the limitations of electrical connections, like wire conductors or cables. He used the natural media, like earth, water or atmosphere, for the transferring of waves, impulses or radiations to cause the desired actions of the subjected device.

Nowadays the fastest and the most accessible transfer media at great distances is the Internet. The advantages of using the Internet for control is due to its versatility, since it provides the user with a series of services, such as File Transfer Protocol, Telnet, WWW, electronic mail, allowing the transmission of information in a simple way, besides being available to many people, having an interface with many multimedia resources, with easy manipulation and low cost.

One of the most important characteristics of a network is its transmission rate. Since usually the commands transmitted for teleoperation need just a small volume of data, with the exception of video feedback, it is not a difficult task to implement teleoperated device through the Internet[5].

Usually there are four types of data that needs to be transmitted in the case of a teleoperated device, as emphasized by YE Xiu-fen et. al in [6]:

- a. Administration data – access control and configuration data: small data package, without real-time restrictions, need a reliable delivery, once-for-all transfer;
- b. Control commands – velocity, angles, rotation steps, displacement: small data package, real-time, in the case of data losses are preferred the last transmitted data;
- c. Image data – the most important and costly feedback data: periodical transfer, real-time, needs a large transfer bandwidth, in case of data losses is preferred the last transmitted data;
- d. Other data concerning the environment – light intensity, distance to the object: small data package, real-time, in case of data losses are preferred the last transmitted data.

Therefore it is clear that data communications in a teleoperated system require real-time delivery except for the once-for-all administrative data. The Internet can provide real-time services, so today it is well known the term of Internet-based teleoperation as referring to a system that can be invoked and controlled remotely by a human operator via the Internet to provide services such as remote-sensing, tele-inspection, tele-mobility, tele-manipulation, etc.

## **2. System Architecture**

Our system software employs the client-server architecture for device control and feedback data. In this model the device is the laser induced fluorescence scanning system that will be described later, with a video camera mounted on top of it. The Server is personal computer connected with the device, and must have the LabView Web-Server tool that allows the publishing of the user interface, which is a VI file, as a web page. On the client side there is a web browser on any computer that must have installed the browser plug-in for the LabView run-time engine, which can be downloaded for free.

The client and the server exchanges information as feedback data and control commands, through the Internet. Communication protocols facilitates the transmission of the operation parameters and the feedback of the motors current position, acquired data and video streaming. The device receives the control commands and the scan parameters for the step motors and the gating time for the spectrometer, and sends back feedback about the scan progress, interrogated spectra, video images. The device also synchronizes the position changing of the laser beam on the area of interest with the acquisition gate time, so that the spectrometer makes an interrogation exactly when the laser beam is positioned on each spot.

### **2.1. The Device**

Laser induced fluorescence scanning device actually is a transportable “black box” that is positioned in front of the surface to be scanned. Once it is connected to the server computer (with an internet connection), and all the equipment inside are ready to go, a user may access the server through a webpage that is located on this server. The “black box” receives commands and service parameters from user via the user interface and the server, and it executes them. A two stepper motors ensemble with a mounted mirror changes the position of the laser beam on the investigated area, as commanded directly or by the scanning algorithm parameters. The scanning algorithm includes the synchronization between the position change and the gating of the acquisition spectrometer.

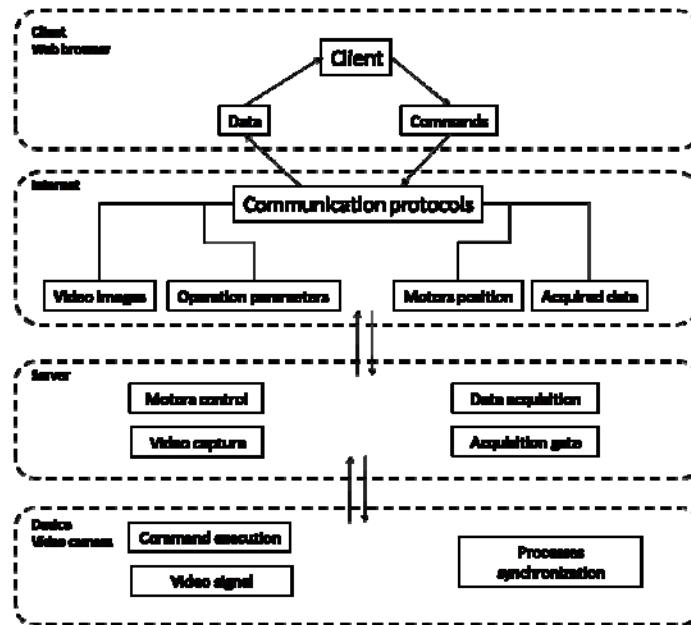


Fig.1 The Client-Server architecture of the teleoperation software

### 3. User Interface Architecture

#### 3.1. The Web-Server

The LabView Web-Server allows the visualization and/or the control of a VI file, remotely, through the LabView application as well as through a web browser. If the VI file is controlled via LabView, it is necessary to install it on the client computer. If the VI file is controlled via a web browser, it is necessary to install a plug-in for that particular browser, that consists in a run-time engine downloadable for free. This plug-in will automatically be installed at the first access of the web page on the created server (in case that the run-time engine isn't already installed).

Therefore, on one side we have a client with the run-time engine already installed, and on the other side we have a HTML file with the <OBJECT> tag that points at the VI file that will be online, viewable and controllable. With this tag, the web browser transfers the the VI file to the web browser plug-in, through the file's URL that this tag contains.

This way, the VI file will be displayed in the browser window of the plug-in, that communicates with the web server in order to establish the interaction between the client and the control panel of the VI file. In order to control the VI file, the client must ask for permission by selecting "Request Control of the VI".

The VI file sends the user's commands to the device through communications the ports (serial, parallel), and receives feedback data within the serial and USB ports and the video streaming

The VI file, which is also the control application, is located on the server computer and it must be loaded in the computer's memory in order to be accessed via the Internet from other locations. The user interface is intuitive so that any new user can learn it easily. It is constituted from several main parts:

### 3.2. The Live Control Panel

This panel includes the commands and parameters that regards the two stepper motor ensemble. The user is allowed to control this ensemble at the desired vertical and horizontal step length, in order to move the laser beam to the area of interest. It also allows the user to set a starting point for the scan and the vertical and horizontal resolution of the scanning grid. The user may stop the scanning sequence at any time. Fig. 2 depicts the controls for the mechanical ensemble with the four directions of movement for the laser beam over the surface, the motor positions feedback. The user is allowed to choose the step length in displacement units with the vertical slider, or to jump to a desired motor position in order to place the laser spot over an area of interest

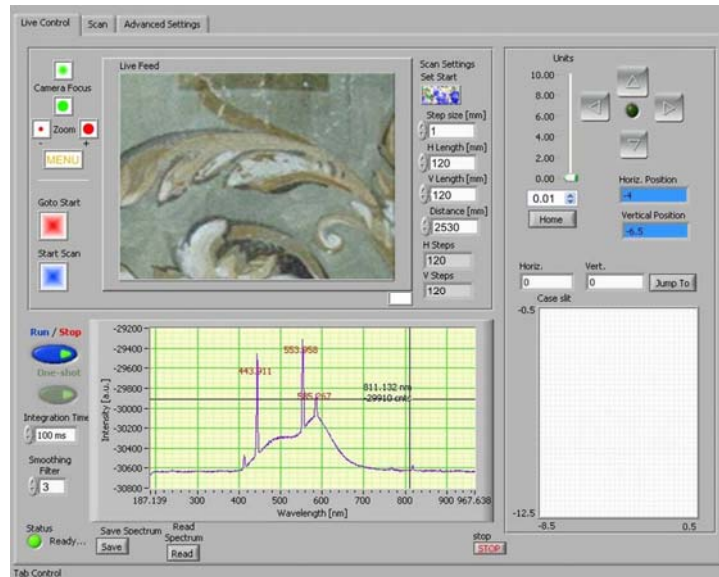


Fig. 2 User interface: the 'Live Control' panel for online video feedback, motors control and spectra acquisition.

To have a visual feedback of the scanning process, live video images are displayed at the same time. The mounted camera on top of the “black box” is connected to a video acquisition board in the server computer. On the same panel with the control buttons a video window displays live images of the studied object, so the operator can easily see the position of the laser spot onto the surface of the object.

To make the preliminary analyzes the user can interrogate, view and save as a text file, the fluorescence spectrum of the irradiated point on the object surface.

### **3.2.1. The Scanning Parameters**

In this panel the user inputs all the necessary parameters for a scan event: the distance to the object, step sizes, total vertical and horizontal lengths of the area to be scanned, the gate time of the spectrometer uses for each point acquisition.

Data acquisition is realized by the spectrometer, which is synchronized with the laser beam scanning. At each change of the laser beam position, the spectrometer receives a triggering impulse to open its slit for the duration of time set by the user as a scanning parameter. The fluorescence emitted by the irradiated surface spreads in all directions [7]. By the means of a lenses system that are focused through the mirror coaxial architecture of the device, on the interrogated spot, part of these emissions are captured and transmitted via optical fiber to the spectrometer. The spectrometer encodes the optical information to digital data and sends it to the server PC as spectra or average intensities of the selected wavelength bandwidths of a spectrum.

### **3.2.2. Data processing**

After the scan is finished, and all the points are interrogated, the user can visualize the intensity distribution maps of the chosen wavelength bandwidths as an intensity gradient map or as a RGB color image, where the three base colors represents the chosen wavelength bandwidth. These maps can be saved as image format files.

For the purpose of this paper, we used an experimental mural painting (Fig. 4a) , with different types of varnishes as depicted in Fig. 4b. The goal was to identify their characteristic spectrum peaks and the varnishes’ distribution over the mural surface. In Fig. 3 there can be observed the scan results.

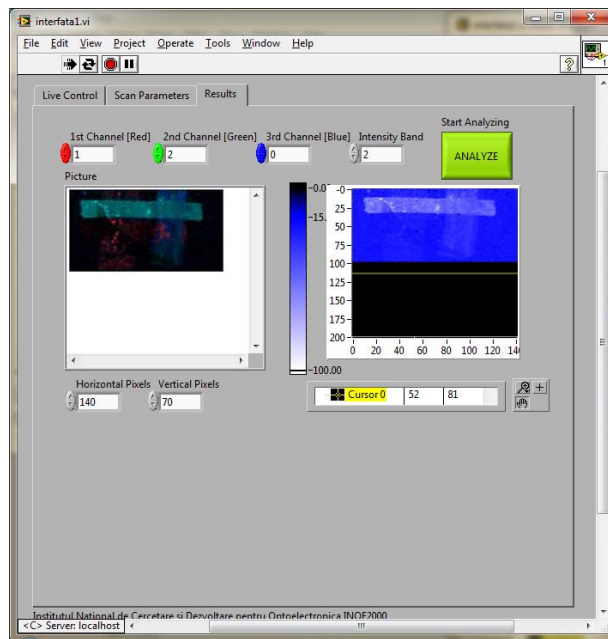


Fig. 3 The 'Results' panel for data processing of the scanning results

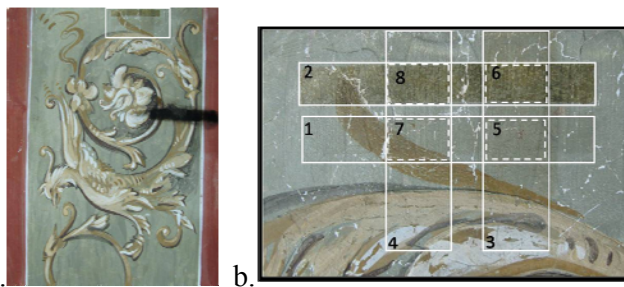


Fig.4 a. Mural painting used in the experiments; b. investigated section

#### 4. Conclusions

We have improved the functionality of the laser induced fluorescence scanning device beyond any limitation imposed by different factors like: the archaeological sites calendar (due to the season changes), long distances between the archaeological site and the restoration specialists, real-time process control and data result delivery in and from any point of the world.

The internet-based teleoperation of the laser induced fluorescence scanning device has been successfully tested from different client locations, with satisfactory results. The system enables Internet users to use the scanning device to investigate in real-time an artwork or a museum artifact with the laser induced

fluorescence technique. The system adopts the client-server architecture. The web-server module of the LabView platform allows the web-publishing of the web page that contains the GUI interface of the system. The server used is the computer connected to the scanning device. A video camera was mounted on top of the system's case in order to monitor the investigation processes on the artwork surface. Using the same GUI interface, the video images are streamed live to the client computer. In order to have a transmission without delays the client must have a good internet connection.

This system has the advantage of being transportable anywhere to the artwork object to be investigated, and can be operated by a specialist from great distances, through a internet connection. This way there can be investigated fragile or very valuable objects that cannot be moved from their environment, and it can be a very important tool for art conservators and restorers.

Further improvements can be made by implementing new software operation functions that can allow more complex investigations.

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