CNR RETRIEVAL OF IMAGES FROM HYPER-SPECTRAL DATA THROUGH INTERACTIVE NETWORK ACCESS (CRISTINA)

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Abstract – The IFAC-CNR hyper-spectral imaging system acquires cube-images at very high spatial and spectral resolution in the 400-900 nm range. The obtained data are used to study the composition of artists' materials, for true-colour reproduction of paintings, and for documenting the characteristic of the underdrawings and *pentimenti*. The current reluctance to make more than limited use of cube-images is due to issues related to the need for efficient filing and computing systems and to the lack of specific image processing skills. The experimental client/server platform developed at IFAC-CNR can be a solution to the hyper-spectral data using issue. The proposed IFAC-CNR platform is presented in this paper.

INTRODUCTION

Plane and/or satellite hyper-spectral imaging techniques have been applied to the study of resources in the country [1,2] as well as to soil survey and mapping [3,4]. These techniques also have been used for the diagnosis and documentation of works of art, mainly focused on paintings [5-8].

The hyper-spectral imaging system assembled at IFAC-CNR is able to acquire cube-images at very high spatial (about 270 dpi on the object plane) and spectral (over 400 bands) resolution in the 400-900 nm range [9]. The obtained data are used to study the composition of artists' materials through their spectral characteristics as well as for reconstructing true-colour reproductions of paintings. Moreover, the electromagnetic radiation in near infrared allows researchers to obtain documentation about the preparatory drawings, *pentimenti*, and previous restoration works, making this type of analysis a valid instrument for art historians, curators, and conservators.

At present, however, the availability of such cube-images is not taken advantage of because of two major limiting issues. The first issue is that the huge mass of data provided by the acquisition system (the CNR-IFAC instrument produces about 140 GB/m^2) makes the data distribution problematic. Currently data sharing usually is accomplished through physical transportation on a hard disk or, in a very sub-sampled form, on a DVD. This approach greatly limits the diffusion of data and imposes long transfer time procedures. Also, the replica costs are high unless the data have been drastically reduced in spatial and spectral resolution. Moreover, even if the diffusion of the wide-band connectivity might suggest having a central station for storing all the recorded data, the global costs in time and energy for transferring data of such dimensions are still very high. In addition, this approach usually would not permit scientists to consult about or to elaborate on the data in a real-time mode from common internet locations/points. The second issue is that analysing this kind of data requires efficient filing and computing systems and specific skills in image processing. Furthermore, in this specific field, unlike elsewhere, the users do not need the entire data set, but only portions of it obtained as results of well-defined and homogeneous processing operations [6].

In this context the achievement of an experimental client/server platform, which keeps the filing and processing burdens on the server side and which makes possible the execution of remote standard processing operations through simple web graphical user interfaces could be the solution to the issues associated with using hyper-spectral data in the cultural heritage field. An experimental system of this type is described below.

CRISTINA

CRISTINA (**C**nr **R**etrieval of **I**mages from hyper-**S**pectral data **T**hrough **I**nteractive **N**etwork **A**ccess) is a web-based platform for the management of aggregated data related to hyper-spectral measurements on artworks.

The platform is centred on a database with the functionality of data organization. It is not necessary to locate the aggregated data on the same server of the database; they can be distributed over the internet. A set of tools provide access to the database, and they implement the management, visualization and elaboration of the data [10].

Data organization

Data in the database are organised in a tree structure: the first level is the artwork. The second level is associated of a certain number of elements to each artwork. At the third level each element is a link to a series of measurements groups. Each measurements group is an aggregation of spatial synchronized data, which can be superimposed and compared by both visual inspection and image computation techniques. This means that a reference picture (typically a RGB image), which is shown by default on the data viewer, has to be associated with each measurements group.

This type of data organisation allows researchers to manage both single- and multi-parts of the studied artwork (through elements distinction) by accessing different measurement sets acquired on the same artwork, for example before and after a conservation intervention (through the distinction of measurements groups).

User data access is achieved through a browser which allows data research on the database with several parameters: the browser returns research results and shows a reference thumbnail for each artwork's element; thus the direct access to the visualisation tool is obtained by selecting the desired element.

Visualisation

The visualisation tool is a web application based on IIPImage [11], an advanced system for viewing and zooming ultra high-resolution images. The client-side viewer, a JavaScript application called IIPMooViewer, interacts with the FCGI server application, IIPServer. The server application produces images in the IIPImage exchange format from pyramidal images (TIFF or JPEG) and sends them to the viewer, which takes care of right re-composition and visualisation of the images.

Side by side with the visualisation tool there is a structure for the superimposition of layers on the displayed image. Then these layers can be used to superimpose any kind of data spatially synchronized with the base image, such as images from different acquisition systems or spot/punctual measurements data [12]. Furthermore, an interface for using server side utilities for extraction and elaboration of data from files containing the measurements is available; these routines dynamically interact with the visualisation platform through AJAX-FCGI methods.

Regarding the visualisation, the features available at this time are (Fig. 1):

- presentation of superimposed images and cross-fading effect for a visual comparison of different images;
- presentation of the reflectance spectra extracted from the hyper-spectral data for point of images selected by user;
- presentation of data acquired with other devices (*i.e*. FORS measurements [12]).

Figure 1: a screenshot of the visualization tool with a superimposed layer containing references to a punctual measurement.

Available elaboration tools are:

- extraction of single spectral images, sub-bands, and their composition in false-colour;
- elaborated images using multivariate methods like Principal Component Analysis (PCA) or spectral angle mapping (SMA) for the mapping of pigments;
- extraction of original measurement partition for user specific elaboration;

Data access

All operations performed on the data are controlled by a permission management program based on the type of user. Thus, the system grants access only to a specific section, depending on the user-specific privileges. Presently, there are three different access levels: administrator, standard user, and advanced user.

The standard user has a base access to the system capabilities, such as:

- browse data;
- visualise data;
- request the insertion of new data into the system or perform computations using already loaded data.

The advanced user has all of the standard user capabilities and, in addition to them, he is allowed to:

- have access to a basic computation instruments set, like the tools for the extraction of images from cube-files or for sub-images extraction;
- load new data onto the system.

The administrator has access to all privileges on the system and is able to (Fig. 2):

- load, edit or delete users;
- load edit or delete data;
- access all of the available computational instruments.

The system offers all of the features of an HTML 5.0 based web interface compatible with most recent browsers and mobiles. Furthermore, the entire system is designed to minimise data exchange between client and server, which also minimises the computational resources needed by each. For this purpose, whenever possible, most computationally expensive elaborations that involve the entire object area are saved, archived, and directly accessible for future use. For computationally simple elaborations, like the extraction of the spectra in a point of the image, and for elaborations related to single points or portions of the object area, the elaboration result is not archived. Finally, most elementary computations related to visualisation of results are delegated to the client.

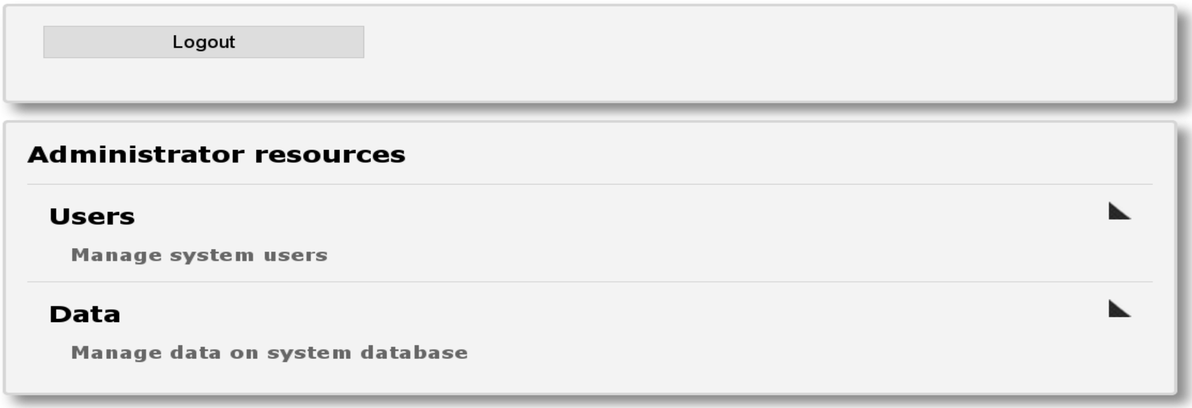

Figure 2. A particular of the administration interface.

Future developments

The main development foreseen in the immediate future is the expansion of the computation and visualisation instrument set to better respond to user feedback and requests. Moreover, the migration to the vector graphic system for diagram visualisation, including the addition of new capabilities, such as graphics superimposition or trace addition, which will provide a more intuitive comparison of results, is already scheduled.

More broadly, this means that the tools available in the experimental hyper-spectral imaging system can be adjusted to meet the management, access, and computational requirements for the analysis of all type of hyper-spectral data.

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