A NEW COMPACT VNIR HYPERSPECTRAL IMAGING SYSTEM FOR NON-INVASIVE ANALYSIS IN THE FINEART AND ARCHITECTURE FIELDS

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Abstract – A new compact Specim IQ hyperspectral camera working in the 400-1000 nm range has been launched on the market. Its use in the investigation of different artworks and under diverse environmental conditions will be presented.

INTRODUCTION

Presently, the study of the materials constituting artworks and archaeological objects can be performed using invasive and/or non-invasive approaches [1]. Preliminary non-invasive approaches are always necessary at the beginning of the study and/or investigation of a work of art, or before initiating any conservation procedure on valuable objects, in order to assist curators and conservators in their decision-making process. Non-invasive methodologies are mainly performed by investigating small (spot size or 1-D technique) and wide (2-D technique) areas, and are focused on the diagnosis, study and conservation of, as well as on the access to, objects of art. Among the imaging techniques a very important role is played by Infrared Reflectography (IRR) and Vis and NIR hyper-spectral imaging (HSI) techniques [2-5]. The former enables the visualization of details underneath the visible surface of a painting, exploiting the partial transparency of the painted layer when subjected to IR radiation. HSI, in addition to the IRR information, provides a spectral and colorimetric characterization of the entire painted surface.

For more than a decade, a number of studies and research projects have been devoted to customize hyperspectral imaging techniques to the specific needs of conservation and applications in museum context [5]. In view of that, HSI has nowadays reached the stage of mature technology and is ready to its large-scale applications. Hence, a novel concept of hyperspectral camera - featuring compactness, lightness and good usability - has been developed by Specim, Spectral Imaging Ltd. (Oulu, Finland), a company in manufacturing products for hyperspectral imaging. The camera, model Specim IQ, is proposed as new tool for novel applications in the field of Cultural Heritage. The novelty of this device relies in its reduced dimensions and weight and in its user-friendly interface, which make this camera handier and reasonably priced than conventional hyperspectral instrumentation. The camera operates in the 400-1000nm spectral range and can be mounted on a tripod. It can operate from short-distance (tens of cm) to long distances (tens of meters) with different spatial resolutions [6]. These technical features furtherly extend the possibility of applications of HSI to new typologies of artworks, both indoor and outdoor, from large-size wall paintings, ceilings, decorative elements and inscriptions to façade of historical buildings and monuments, as well as inspection small details of interest selected on the surface of almost flat objects.

The imaging system, presented on November 30th 2017 in Helsinki, has been tested before its forthcoming official on the market by IFAC-CNR Applied Spectroscopy research group laboratories. In the present communication, some of the first applications to different artworks and under diverse environmental conditions of one of the Specim IQ portable camera prototypes are reported.

Specim IQ camera: technical information

The Specim IQ has been designed to provide a full hyperspectral tool with required features for making hyperspectral imaging possible on different kind of environments (Fig. 1). It differs from other hyperspectral cameras on the market by integrating the hyperspectral sensor with additional color cameras, replaceable data storage and batteries, data acquisition and processing electronics, and an optimized operating system and user interface into a single portable housing. The integrated color cameras support the spectral camera usage by making it possible to direct and point the camera with standard viewfinder image as well as adjust the manual focus of the spectral camera with a normal camera image. By removing the need for additional computers, cabling, power supplies and software, it enables the users to exploit this novel technology in an easy and straightforward way. The rechargeable batteries and standard 32 GB SD memory card for the image data allow approximately 100 measurements to be made with camera without the need to recharge or change the storage media. The operating system is designed in a way that it will guide the user to consider the necessary camera adjustment and data quality validations, without a need to go into details of the hyperspectral imaging technology details. The target on the system design has been to enable users, not familiar with hyperspectral imaging, to successfully start using it in their applications.

Fig.1 - Specim IQ hyperspectral camera

The hyperspectral data acquisition with Specim IQ can be made both outdoor and indoor conditions, with Sun light or artificial, broadband illumination. Depending on the application field, both LED and halogen-based illuminations can be used. In addition to the Specim IQ and possible illumination, a reflectance reference targets are needed to correct the effect of the illumination and ambient environment effect from the data, and make the measurements made in different conditions comparable with each other's. Like majority of the hyperspectral cameras, Specim IQ does not provide the image with full spectral content with single snapshot, but the hyperspectral image is acquired by making a line-scan over the target area. The camera is designed in a way, that there is no need to move the camera or target, but the image scanning is performed with internal mechanisms. Due to image collection by scanning, the process takes in normal conditions from seconds upwards, so it is recommended to use Specim IQ with a standard tripod.

The camera visualizes the hyperspectral data immediately after the measurements and the user has possibility to add metadata to the measurement. It is also possible to use the bundled Specim IQ Studio software to create material identification models for the hyperspectral data. These can be installed as applications to the Specim IQ, and when operating the camera with an application, the camera will also process the data and provide the processing results visualization for the user. In addition to the bundled software, the hyperspectral image data format is compatible with majority of the other hyperspectral data processing software's available in the market.

The Specim IQ covers the 400 – 1000 nm spectral range and provides 7 nm spectral resolution with 3.5 nm spectral sampling – suitable for majority of the materials having spectral response in this wavelength range. The resulting image from Specim IQ is 512 x 512 pixels, with all the pixels containing 204 spectral samples. The camera saves both unprocessed and processed data and the single measurement is approximately 300 MB (Table 1).

Table 1 Technical specifications of the Specim IQ hyperspectral camera

Wavelength band	400 – 1000 nm
Spectral resolution FWHM	7 nm
Spectral bands	204
Image resolution	512 x 512 pixel
F/number	1.7
Peak SNR	> 500:1
Data recording time	~ 1 s – 260 s (Depending on the illumination level)
Object distance	150 - ∞ mm
FOV	40 deg
FOV at 1 m	0.5 x 0.5 m
Camera interface	USB Type-C
Data format	SPECIM Dataset with ENVI compatible data files
Size	207 x 91 x 126 mm
Weight	1.3 kg
Operational temperature	+0°C - +40°C
Operational humidity	< 95% non-condensing

Specim IQ camera: case studies

The first case-study was performed at the Stefano Scarpelli painting conservation studio on the 19th century canvas painting "Saint Catherine carried by the Angels on Mount Sinai" (Santa Caterina trasportata dagli Angeli sul monte Sinai, 49.6 cm x 67 cm, private collection) by the Austrian painter Karl von Blaas (1815 - 1894).

Fig. 2 VNIR Specim IQ camera during the acquisition of the hyperspectral imaging data.

The data acquired were used to identify some of the pigments used by the artist and to map their distribution over the region of interest by using the spectral angle mapper (SAM) procedure that is incorporated in the software uploaded in the camera itself (Fig. 2). It was found, for instance, that the pigment used for depicting the blue and bluish areas was Thénard's blue (also known as cobalt blue) pigment, an important synthetic pigment used by artists since the 19th century. In Figure 3 is reported the image that appeared in the screen of the camera in which it is reported on the blue right sleeve of the angel the pixel from which the reflectance spectrum, reported in the graph at the right, was extracted. The absorption features in the 500-700 nm range and the whole spectral shape of this spectrum made it possible to identify the blue pigment as cobalt blue [7].

Fig. 3 image displayed in the Specim IQ back screen with reported the reflectance spectrum of the selected pixel.

Afterwards, the areal distribution of this pigment was mapped using the SAM procedure with a wide tolerance thresholding option selected from the set maximum angle (in radians) area by using the SAM mask tool, as reported in figure 4.

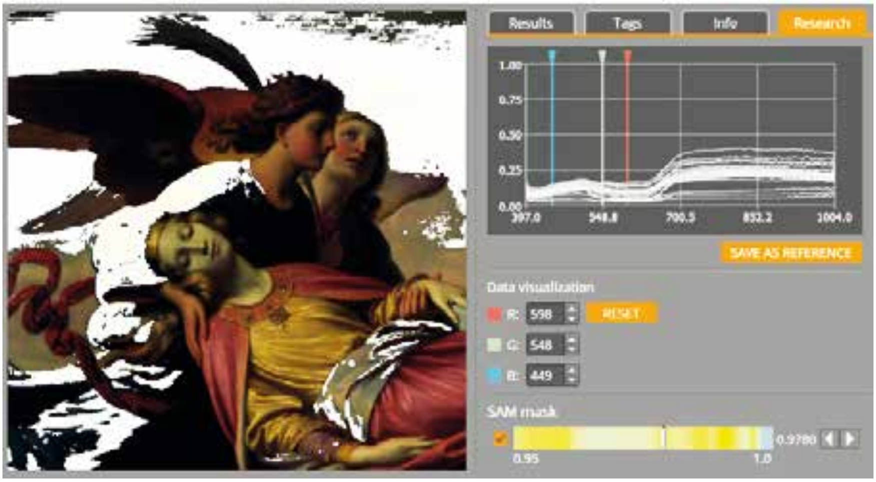

Fig. 4 distribution map of the pigment cobalt blue (in white) on the imaged area of the painting using the SAM procedure of the software of the camera and as reference the spectrum selected in figure 3.

Subsequently, it was tested the usability of the Specim IQ camera for remote acquisitions on outdoor large size painted surfaces, hardly to reach because of their location, such as one of the painted lunette in the Sant’Antonino cloister of the San Marco Museum in Florence [6]. This cloister has been decorated with mural paintings by different artists over three centuries starting from the 15^{th} century. In the 17^{th} century, a cycle of lunettes depicting scenes from the life of Sant'Antonino, who was responsible for the rebirth of the monastery and an important figure for the Dominicans monks. The investigated lunette is located in the upper part of the north wall of the cloister and was painted by the Florentine painter Fabrizio Boschi (1572-1642)(Fig. 5).

Fig. 5 VNIR hyperspectral camera during measurements in the Sant’Antonino cloister at the Museum of San Marco, Florence.

Finally, the imaging system was tested on a 15^{th} century Florentine illuminated book of the Biblioteca Medicea Laurenziana in Florence [8]. Some of the miniatures of the book have been attributed to Beato Angelico, although the manuscript attribution is still subject of investigations.

The data acquired on the easel- and wall-paintings as well as the illuminated manuscript evidenced the noteworthy potentialities of Specim IQ camera in the Cultural Heritage application field. Moreover, its use makes it possible to extend the use of hyperspectral imaging technique to new categories of artworks or artworks /archeological objects located in unfavorable environments, which result difficult to be investigated with the most traditional models of hyperspectral devices.

Summary

From the first data acquired with the first release of the Specim IQ compact hyperspectral camera it was found that this camera is a perfect imaging device for preliminary, quick diagnostics on different typologies of 2D polychrome artworks and in different environments. The performances of the Specim IQ camera in terms of spatial resolution and spectral interval coverage indicate that this device cannot be considered as a substitute of high-precision hyperspectral instrumentation specifically tailored for applications on paintings, especially when high-quality image documentation is required. However, it can be considered as an ideal tool to complement other analytical techniques and to guide the decision making process in planning diagnostics campaign which encompass a multi-analytical approach.

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