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Multispectral Imaging as a Preservation and Valuation Tool at the Minas GeraisPublic Archive, Brazil: A Case Study on an 18th-century Illuminated Manuscript.

Alexandre Cruz Leão[1]; Alexandre Oliveira Costa[2]; Márcia Almada[3]; Rodolpho Zanibone[4]; Luiz Antônio Cruz Souza[5].

[1,2,3,4,5] Federal Universityof Minas Gerais; Belo Horizonte, Minas Gerais/Brazil; alexandre.leao.ufmg@gmail.com

Abstract

Multispectral Imaging has become an indispensable tool for Cultural Heritage materials and objects analyzing, documenting, and visualizing. This study delves into applying this technique to an 18th-century illuminated manuscript at the Minas Gerais Public Archive, Brazil. Currently undergoing restoration intervention at The Federal University of Minas Gerais, the manuscript exhibits faded writing due to moisture, and the application of multispectral imaging (UV, Visible, and IR) with seven different wavelengths proves highly effective in recovering lost information. The light source was provided from LED and Halogen Lamp, and the result shows a very clear text on the manuscript after the digital processing by ImageJ and PCA. The Minas Gerais Public Archive, established in 1895, plays a vital role in safeguarding the state's documentary and historical heritage. It was the first-time multispectral imaging was applied to cultural objects in Minas Gerais.

Introduction

Multispectral Imaging (MSI) has become a powerful tool for examining and documenting Cultural Heritage assets [1]. This technique involves capturing multiple images of an object illuminated at various wavelengths, including Ultraviolet Radiation, Visible Light, and Infrared Radiation — beyond the spectrum of human sensitivity [2]. Processed through specialized software, these images empower conservation scientists, researchers, museum professionals, archivists, and experts to discern original components, faded or obscured inks and writings, and the effects of various factors on heritage objects, thereby playing a pivotal role in authentication and preserving the artifact's originality [3].

Moreover, Multispectral Imaging in Cultural Heritage exploration unveils novel dimensions by seamlessly merging visible and non-visible aspects of the same object, providing additional data and insights that enrich our understanding [3]. Importantly, this entire process is non-invasive, aligning seamlessly with the latest principles of Conservation Science.

Another issue concerning Multispectral Imaging relates to its various possible applications: in addition to scientific examination, documentation, visualization, and analysis of materials of Cultural Heritage [1], it also allows for collecting a wide range of information regarding the analyzed cultural artifact: characterization of pigments and dyes, comparisons of inksassessment of the impact of environmental conditions and conservation interventions. Moreover, it enables the evaluation of the artifact's origin and issues related to forgeries, making it suitable for forensic investigation. Thus, it has become a technique of great assistance to scientists, researchers, conservators, museologists, and other professionals working in cultural heritage.

The present study focused on recovering faded information from a rare 18th-century illuminated manuscript associated with the Irmandade de NossaSenhora do BomSucesso do Caeté in Minas Gerais, Brazil. This manuscript is part of the Minas Gerais Public Archive collection, an institution with a century-long history in Minas Gerais. Beyond the restoration efforts, this study significantly contributed to institutional scientific dissemination.

Problem

The central subject of our study is an 18th-century illuminated manuscript containing the statutes of NossaSenhora do BomSucesso brotherhood sited in Vila Nova da RainhadoCaeté, a village founded in 1714. This codex comprises 39 folios crafted from rag paper, measuring 310 x 220 x 30 mm. Notably, 21 of these folios showcase intricate ornamentation in gum-based tempera on the initials and frontispiece, while the remaining 11 feature 18th-century cursive writing in iron gall ink [4] (*Figures 1 and 2*).

Figure 1: *Manuscript – Fronstispiece. Photo: Costa; Leão*

Figure 2: *Manuscript – Folio 13. Chapter VI. Photo: Costa; Leão*

The local brotherhoods played a crucial role in colonial Brazilian society, supporting the members' lives, including spiritual assistance, religious celebrations, and support for illness, widowhood, and funeral rituals. Despite having a general normative nature, their statutes documented specific situations of the historical context in which they were written and applied [4].

The authorship is attributed to an unidentified calligrapher who worked in the Captaincy of Minas Gerais in the early 18th century. Although, the researchers don't yet know his identity and has been identified seven of his works, the oldest dating back to 1713. The main characteristics of this calligrapher are the high quality of the gilding, the writing, and his style, which creates fantastic birds and flowers with inks in shades of red and blue [5].

Currently undergoing a restoration process, the manuscript's conservation status is precarious, marked by significant losses resulting from insect attacks. These damages compromise its material integrity, mechanical strength, and legibility. Moreover, the impact of moisture on certain folios has led to the solubilization of the iron gall ink, making the text illegible within the affected areas. The application of the Multispectral Imaging technique was explicitly limited to Folio 24, the most damaged section, presenting a substantial operational challenge due to its fragile conservation state *(Figures 3 and 4).*

Figure3: *Manuscript – Folio 24. Photo: Costa; Leão*

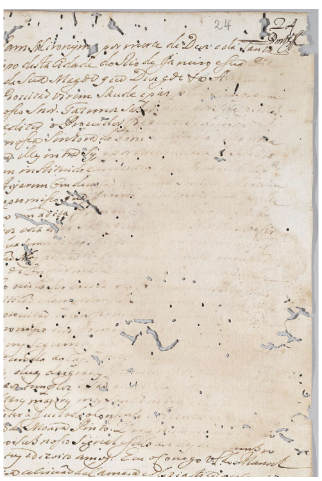

Figure 4:*Manuscript – Folio 24 Detail.*
Photo: Costa; Leão

Folio 24 records the confirmation and approval of the brotherhood statutes by the Bishop of Rio de Janeiro, Dom Francisco de Sam Hironymo, and by the ecclesiastical forum. This document, dated December 10, 1718, represents an important document legitimizing the formation and commitments of the Brotherhood.

The research on this manuscript is conducted in an interdisciplinary approach, involving collaborations across various fields of study. Historians, chemists, and conservators work together to investigate its history and material characteristics that guide conservation treatment decisions.

Approach

The research employed a variety of equipment, including a Reprovit stative column, a modified full-spectrum DSLR camera (Canon EOS T6), and a Canon 50mm f/1.8 lens. The camera was converted to full-spectrum by disassembling it and removing the factory-installed IR filter covering the digital sensor, thus restoring its original sensitivity and enabling it to capture information ranging from 360nm to 1000nm [6].

The lighting setup comprised Youngnuo YN660LED RGBW 45W reflectors (R, G, B, and White), electronic fluorescent lamps, Black Light BLB 365nm 36W, UV LED flashlight 365nm, 300W halogen lamp, and Kodak 2E and 87 filters. Regarding the lighting sources, despite being simple, they positively contributed to the experiment, providing the expected result. Below, is present the spectral distribution, starting with the spectrum of the Youngnuo YN660LED RGBW LED stick.

Figure 5 displays the spectral distribution graphs of the white light provided by the Youngnuo 660 LED-RGBW stick configured at 5000 K. This White = Visible Light configuration exhibited a CRI of 96, demonstrating the superior quality of this LED. The full-spectrum configuration covers the entire spectrum of visible light, from 400nm to 700nm. The spectral representations in the White configuration were obtained using X-rite's i1Basic PRO Spectrophotometers, which cover the wavelength range of 380nm to 730nm, as shown in the spectral curve graph on the left in *Figure 5*. The spectral curve on the right in *Figure 5* was obtained using the Sekonic C7000 Spectromaster, which collects spectral information in the wavelength range from 380nm to 780nmThe lighting setup comprised Youngnuo YN660LED RGBW 45W reflectors (R, G, B and White), electronic fluorescent lamps, Black Light BLB 365nm 36W, UV LED flashlight 365nm, 300W halogen lamp, and Kodak 2E and 87 filters.

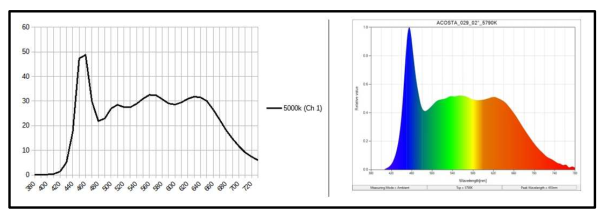

Figure 5: *Spectral distribuition of Yongnuo YN 660 LED stick- White*
Authors: Santos, Costa

In photography, full-spectrum white lighting, specifically visible light, benefits from the excellent color reproduction index (CRI 96) of the Youngnuo YN660LED lighting source, capable of reproducing the colors of the photographed object more faithfully. Particularly in Multispectral Imaging, in our case, this is important because it allows more accurate color reproduction characteristics of the cultural artifact imaging. When combined with the contrast differences provided by images captured under lighting at discrete wavelengths (Red, Green, and Blue), it becomes possible to collect detailed information regarding the cultural artifact under study. By transforming the images into black and white, the contrasts become more pronounced, which benefits the subsequent processing stages.

In *Figure 6*, is presented the graphical representations of the normalized spectral curves corresponding to the discrete wavelengths of Red, Green, and Blue (RGB) provided by this lighting source. The spectra below were obtained using the i1 Basic Pro UVcut Spectrophotometer from X-rite.

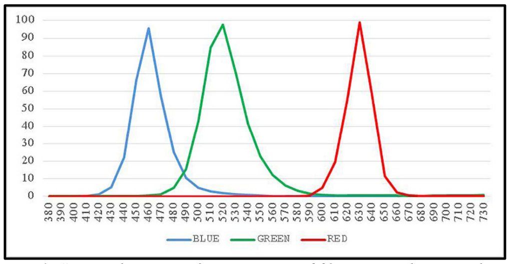

Figure 6: *Spectral curves of Yongnuo YN 660 LED stickin wavelenghts Red, Green e Blue. Authors: Santos, Costa*

The Red, Green, and Blue wavelengths of the Youngnuo source have peak radiation emission at 640nm (Red), 520nm (Green), and 460nm (Blue), respectively. Generating images at discrete wavelengths allows for filtering specific information enabled by that wavelength, which influences the results of image stacking in the ImageJ software and subsequent processing in the PCA (Principal Component Analysis) plugin.

The graph below, *Figure 7*, represents the spectral curve of the halogen lamp used in the experiment, which covers the wavelength range from 380nm to just beyond 1018nm, thus reaching a small fraction of the Ultraviolet Band, spanning the entire Visible Band and extending into the Near Infrared (NIR). To generate images exclusively in the Infrared band of the Electromagnetic Spectrum, it is necessary to overlay a filter that blocks the entire visible range in front of the lens. The Kodak 87 Filter, which blocks radiation emissions below 720nm, was used in this case. This captures essential information about the reflection of infrared radiation incident on the object under study. Infrared radiation can penetrate certain surfaces and reveal underlying aspects inherent to the photographed object. For example, in the case of a painting, it is possible to show the artist's preparatory drawings, erasures, and regrets, among other information underlying the pictorial layer. Multispectral Imaging greatly contributes to the sum of all wavelengths used due to its ability to penetrate surfaces, especially when revealing aspects not visible to the naked eye, a characteristic of paramount importance when the goal is to reveal erased or faded writings.

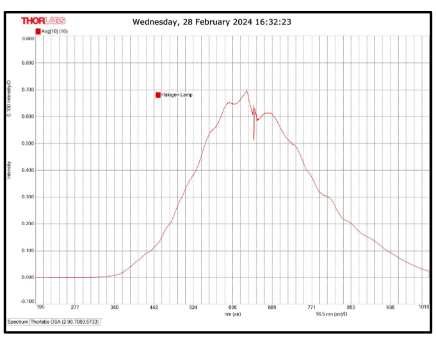

Figure 7: *Spectral curve of Halogen Lamp Mako300 W. Author: Leão*

Below, is presented the spectral curves of the ultraviolet lighting sources: the electronic fluorescent lamp Black Light BLB 365nm and the forensic UV flashlight 365nm. The property of ultraviolet radiation in this wavelength range (365nm) to induce fluorescence in certain materials allows professionals dealing with Cultural Heritage to analyze the chemical composition of some elements, the presence or absence of interventions, old or new, aspects of the pictorial layer, and varnishes used in the work, among other investigative possibilities. It's worth noting that the fluorescent UV lamp Black Light BLB has radiation peaks at 365nm and 403nm. In contrast, the forensic UV flashlight has a well-defined radiation peak in the 365nm range. Using these two UV light sources made it possible to compare their performance. The UV flashlight allowed for more excellent definition in the contrasts of the generated image, which was of great importance in the summation of images and obtaining results. Below are the spectral curve representations of these two UV sources. *Figure 8and Figure 9.*

The spectra of the halogen lamp and the two ultraviolet illumination sources were generated using the ThorLabs CCS200/M spectroradiometer, 200nm-1000nm band spectrometer, and metric.

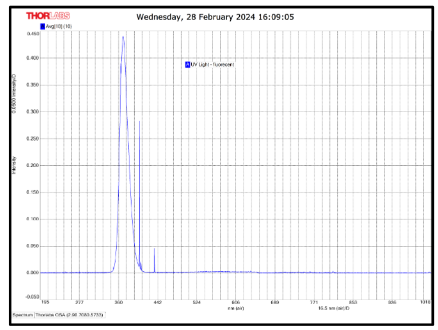

Figure 8: *Spectral curve of UV FluorescntLamp Black Light BLB. Author: Leão*

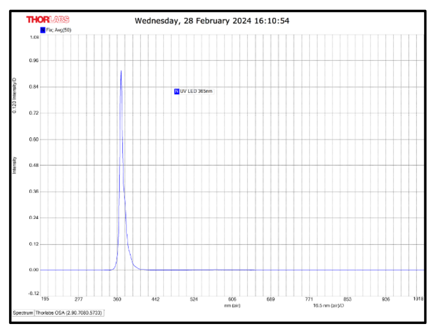

Figure 9: *Spectral curve of UV Flashlight. Author: Leão*

Regarding ultraviolet radiation, images were generated by the camera with the Kodak 2E Pale Yellow Optical Wratten Filter, which blocks radiation emissions below 415nm without the overlaid filter. In subsequent analyses, it was decided to use the UV images generated from the electronic Fluorescent UV lamp with the filter and from the UV LED flashlight without the filter, aiming to achieve the best result.

The photographic set-up for the procedures consisted of a stationary column for fixing the camera and studio tripods for fixing the lighting sources, (Figures 10-a and 10-b).

Figure 10-a: *Photographic Set-Up Photo: Leão*

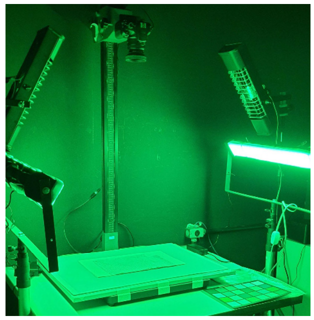

Figure 10-b: *Photographic Set-Up Photo: Leão*

A total of 8 images were generated, *Figure 11*,in RAW format (uncompressed) and processed on a computer by Adobe Bridge CS6®, Adobe Camera RAW 9.5®, and Adobe Photoshop CS6®.

For the best results, correct exposure is necessary, with sharp focus and the lowest ISO to reduce noise. Is important the position and wavelength of the lighting sources, the presence or absence of filters and the cultural objects photographed themselves.[8] Another fundamental fact is that the camera and the object must necessarily remain static, in the same position, at the risk of the images being unapproved and lost. Loss of registration makes stacking images in Image J and consequently the process of submitting them to PCA unfeasible. All metadata and camera settings must also be recorded for the purposes of occurring and repeating procedures.

These images were generated under the aforementioned lighting conditions, namely: the two UV light sources, the 5000K white light (Visible Light), and the Red, Green, and Blue wavelengths provided by the Youngnuo YN660LED, and in the near-infrared (NIR) region, the halogen lamp with the Kodak 87 filter overlaid on the camera lens was used. The function of the Gretag-Macbeth ColorChecker® [9] chart is to synchronize the white balance and photometry of the Visible Light image, correcting its colorimetry.

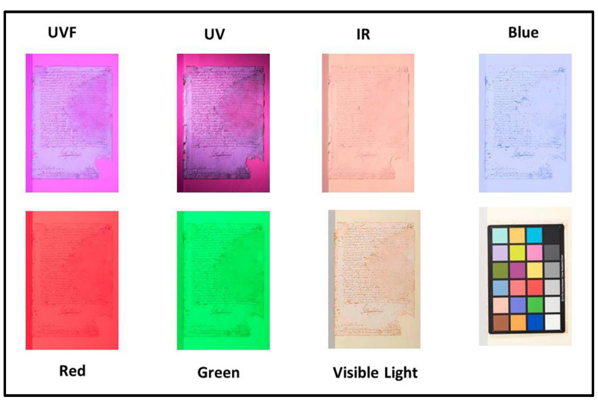

Figure 11: *Images generated at various wavelengths..*
Photo: Leão,Costa

The images were converted to monochromatic TIFF format with 16 bits, and additional processing was performed using ImageJ/PCA software. A. *Figure 12* displays the monochromatic images thus processed.

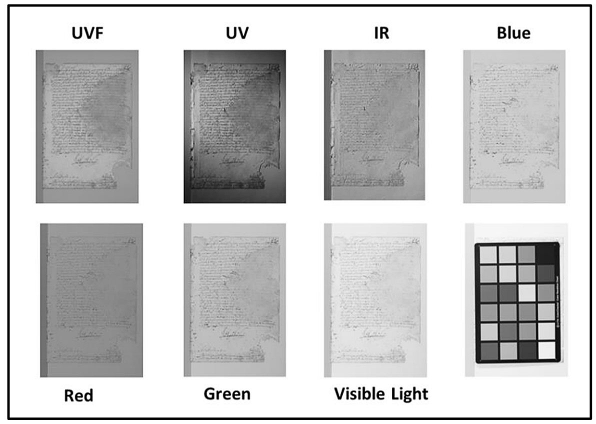

Figure 12: *Images converted to monochrome, 16-bit TIFF format*
Photo: Leão,Costa

Notably, all the equipment utilized in this research was generously provided by the researchers and institutions involved, namely, iLAB – Scientific Imaging Laboratory at Fine Art School, UFMG – Federal University of Minas Gerais, Brazil; PrismaLAB – Technical and Scientific Imaging, LaGrafi, and the CECOR – Conservation and Restoration Center. It's worth mentioning that no imaging company supported this research.

Results

Were generated eigth RAW images of Folio 24, processed them in Adobe Camera RAW®, converted them to monochromatic, saved them as TIFF files in 16-bit format, and proceeded with additional processing in the ImageJ software. In ImageJ, we stacked the images and applied enhancement using the PCA (Principal Component Analysis) plugin. This process resulted in the creation of two PCA images that exhibited a substantial improvement in visualization when compared to the initial Visible Light image, Figure 13-a; PCA image negative, Figure 13-b, PCA image positive, Figure 13-c.

Figure 13-a: *Manuscrispt – Folio 24 Visible Light. Photo: Costa; Leão*

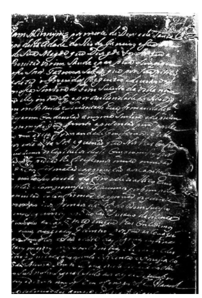

Figura 13-b:*Manuscrispt – Folio 24 PCA negative. Photo: Costa*

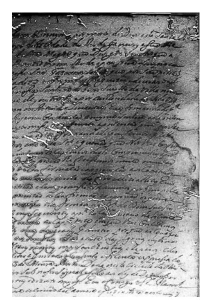

Figura 13-c:*Manuscrispt – Folio 24 PCA positive. Photo: Costa*

Conclusion

Multispectral imaging in this project marked its first experience in Minas Gerais. This accomplishment serves as compelling evidence, highlighting the credibility of multispectral imaging in this investigative context. Moreover, the partial recovery of legibility in the faded writing on Folio 24, along with the ongoing restoration efforts focused on the materiality of this rare illuminated manuscript, underscores the necessity of an interdisciplinary approach in dealing with cultural heritage objects.

The technique played a crucial role in revealing previously faded information in the manuscript, allowing for reading textual information lost over time. These recovered data were essential for accurately dating the manuscript and understanding the circumstances surrounding the formation and activities of the NossaSenhora do BomSucesso brotherhood. This innovative approach demonstrates how technology can be effectively employed in preserving and interpreting historical documents, contributing to our understanding of the past and highlighting the social function of public archives in society.

This first part of the research was rewarding for everyone involved. The most significant difficulties are finding the type of lighting suitable for the experiment, especially LEDs with a stable frequency, high CRI, and capable of bringing reliability to the generation of images. In Brazil, the researchers do not find manufacturers of lighting systems based on monochromatic LEDs of varying quality and wavelengths capable of providing better performance to the process, refining and expanding the number of spectral bands offered. Despite these circumstances, the results achieved were entirely satisfactory and positive.

It is now up to Folio 24 to complete the experiment, improving the readability of the document and making it ready to the full paleography transcription. Regarding the future of the Project, the researchers intend to optimize, in general, the necessary equipment, both in lighting, expanding the number of spectral bands, and generating images. In this way, this research contributes significantly to preserving and enhancing the Brazilian Cultural and Archival Heritage.

Acknowledgement

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Author Biography

Alexandre Oliveira Costa –researcher at iLab – Scientific Imaging Laboratory – Fine Art School – UFMG, since 2015. Conservation and Restoration undergraduate (UFMG - 2018) Imaging professional with wide experience in photography, ultraviolet, infrared, ranking light.

Alexandre Leão- Professor - Photography Department at Fine Art School - UFMG, since 2008. Doctor of Arts (2011) with emphasis on Image Technology (Research about Kodak Color Target Q-13). He works professionally with photography, scanning, color management for digital imaging, colorimetry, multispectral imaging, scientific imaging documentation for cultural heritage. ICOM member (International Council of Museums) and IS&T (Society for Imaging Science and Technology) associate. iLab and PrismaLab Coordinator at UFMG. Visiting Researcher at University of Leeds (Ago 2018 – Jul 2019)

Márcia Almada - is a Professor at the UFMG, teaching in the Conservation and Restoration of Movable Cultural Heritage program and the Graduate Program in Arts. She holds a Ph.D. in History from the same university and completed post-doctoral research at the University of Campinas and the Federal University Fluminense/University of West Attica (Greece).

Rodolpho Antonio Pereira Zanibone – researcher at LaGrafi (Graphic and Film Documents Conservation-Restoration Laboratory) – Fine Art School - UFMG. Conservation and Restoration undergraduate (UFMG - 2021)

Luiz Antônio Cruz Souza – Full Professor – Heritage Conservation Science. UFMG. LACICOR – Conservation Science Laboratory coordinator – CECOR – Center for Conservation and Restoration of Cultural Properties – School of Fine Arts – Federal University of Minas Gerais. Ph.D in Chemistry.