

TECHNICAL PAPER

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PHOTOSHOP AND MULTISPECTRAL IMAGING FOR ART DOCUMENTATION

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Abstract

Adobe® Photoshop® has been applied already in a number of scientific fields. This paper presents some of Photoshop's segmenting and blending tools and discusses their application for art examination and documentation, with a particular focus to speed up the workflow of professionals working in museum conservation. These tools produce results comparable with those of much more expensive and difficult to use scientific software with the relevant advantages that come from using mainstream software with a large professional user base. This effort matches the current interest in the conservation sector to pursue low-cost methods and commercial equipment. Specifically this paper presents the semiautomatic identification and quantification of retouches and losses by editing and analyzing the ultraviolet fluorescence images. It also shows the use of luminosity blending mode applied for the color-aided visualization of cadmium pigments in the infrared fluorescence images, the enhancement of infrared images and the preliminary examination of multispectral images to guide in planning further analytical measures.

1 Introduction

Adobe® Photoshop® is an untapped powerful tool for conservation and art documentation professionals examining an artifact using multispectral imaging (MSI). There are few examples of image analysis software developed or adapted specifically for art examination^{1,2}. Otherwise, there is software for scientific imaging analysis which provides fine quantitative analysis but is either costly or, when available with free access^{3,4}, difficult to use. Photoshop has been applied in a number of scientific fields already. It was proposed for semiautomatic identification of anatomical structures in MRI imaging⁵ and breast cancer research⁶ and there is specific literature regarding its use for scientific imaging⁷. The implementation of a commercially available image editing software such as Photoshop for the art documentation workflow has a number of advantages: a) Photoshop is likely to be commonly available and updated longer than any software developed specifically for the tiny field of art examination; b) Photoshop is the industry standard in digital imaging. It is powerful and actually has the best image analysis tools for a high quality, first approximation qualitative analysis of artworks. Furthermore, there are a number of plugins available to enhance its capabilities specifically for scientific use; c) The scripting and automation tools can be tailored to the needs of art documentation and facilitate the batch processing of multiple images providing workflow efficiency. Photoshop can be customized to be a useful MSI analysis tool without requiring any coding skill, unlikely for a conservator to have; d) Using a mainstream software with a large professional user base allows for sharing the material using the same platform without issues with file conversion; e) There is a great interest in the conservation sector on techniques that require low-cost, simple and commercial instrumentation; such as a digital cameras modified for MSI⁸ and the Reflectance Transformation Imaging technique⁹. This paper describes some Photoshop features which are of use for specific tasks in art examination and

documentation with MSI: the semiautomatic identification and quantification of retouches and losses; color-aided visualization of underdrawing and cadmium pigments; and the preliminary examination of MSI images to guide in planning further analytical measures. These applications are useful for the workflow of professionals working in museums conservation and in art examination to reduce time in preparing comprehensive condition reports, particularly for large collections.

2 Experimental

2.1 Materials

These methods were tested on a pigments board, a mock up painting and on 2 real artworks. The pigments board, called *pigments checker*, is a collection of 56 historical pigment swatches applied using gum Arabic as a binder on a cellulose and cotton watercolor paper, acids and lignin free, commercialized by "Fabriano", 270 gr/m². This paper is not treated with optical brighteners, it's slightly UV Fluorescent, and it reflects infrared. Two cross-hair lines, 0.2 mm (vertical) and 0.4 mm (horizontal), were printed on each swatch of paper before the application of paint, in order to have a means to evaluate the pigment transparency in the infrared imaging. Full resolution MSI images of the pigments checker and details regarding the pigments are available¹⁰. A mock-up oil painting, Madonna and Child, was prepared with historical pigments, retouches with modern pigments and an underdrawing and a copying grid. As for real artworks, an oil painting on canvas representing Madonna and Four Angels, (Sicilian artist, late 18th century, private collector) and a Sicilian wooden cart piece painted by Vincenzo Di Mauro in the 1920s, belonging to the collection of Domenico Di Mauro, one of the few remaining Sicilian cart painters, were used.

2.2 Multispectral Imaging

This study presents MSI images acquired in 4 spectral bands: ultraviolet (360–400 nm), visible (400–780 nm), and infrared (780–1700 nm). The acronyms for the MSI methods are: VIS (Visible), IR (Infrared)^{11–14}, UVF (Ultraviolet Fluorescence)^{15,16}, UVR (Ultraviolet Reflected)¹⁷, IRF (Infrared Fluorescence)^{18–20} and IRR (Infrared Reflectography)^{21,22}. A part from the IRR, all the other MSI images were acquired with a Nikon D800 DSLR (36 MP, CMOS sensor) digital camera modified for "full spectrum", ultraviolet-visible-infrared photography (between about 360 and 1100 nm). The filter set was: a) For Ultraviolet Reflected (UVR) photography, the B+W 403 filter used together with the X-Nite CC1 filter. B+W 403 allows just the UV light to pass, and X-NiteCC1 is necessary to stop the IR produced from the UV lamp; b) For Visible (VIS) photography, just the X-NiteCC1 filter; c) For UV Fluorescence (UVF) photography, the B+W 420 stops the reflected UV, and the X-NiteCC1 excludes any infrared from the UV lamp; d) For Infrared (IR) just the Heliopan RG1000. Infrared Reflectography (IRR) was performed with an InGaAs camera (320x256 pixels)

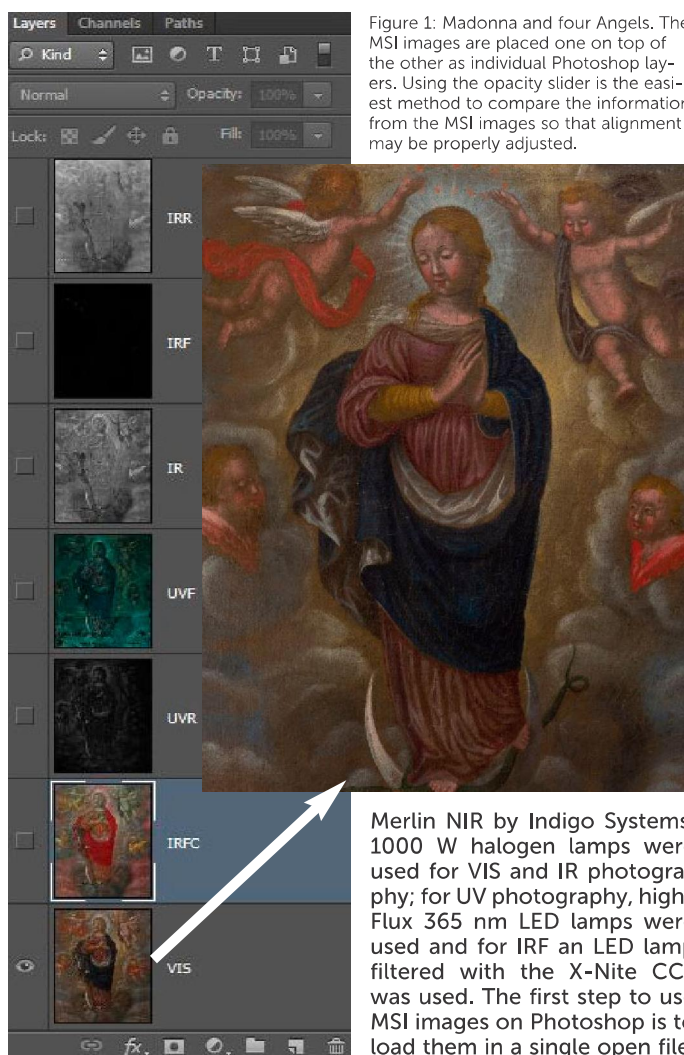


Figure 1: Madonna and four Angels. The MSI images are placed one on top of the other as individual Photoshop layers. Using the opacity slider is the easiest method to compare the information from the MSI images so that alignment may be properly adjusted.

Merlin NIR by Indigo Systems. 1000 W halogen lamps were used for VIS and IR photography; for UV photography, high-Flux 365 nm LED lamps were used and for IRF an LED lamp filtered with the X-Nite CC1 was used. The first step to use MSI images on Photoshop is to load them in a single open file,

one on top of the other as layers and register them so that they are properly aligned, Figure 1. Layers are a very useful feature; they can be used to contain labels, notes and reference positions for analytical examinations; they can contain image adjustments so the original image can be preserved, and they can be modified or deleted without compromising the original image. It must be pointed out that the methods suggested in this paper are not unique but indeed the same tasks can be performed using a number of alternative tools and methods in Photoshop. This represents the workflow adopted by the authors, having optimized the process over the years of working in this field.

2.3 X-ray Fluorescence Spectroscopy

Qualitative elemental analysis was carried out using portable x-ray fluorescence spectroscopy (pXRF) with a handheld Bruker AXS Tracer III-SD[®] (Kennewick, WA USA), equipped with a Rh anode for the production of x-rays and operating at 40 keV maximum voltage. Spectra were collected by means of a Si-SDD detector with a resolution of 140 eV, FWHM at Mn (5.9 keV). All measurements were performed in air, with a voltage of 40 kV and a current of 11.2 μ A. The scans were taken with comparatively short acquisition times, only 30 s

versus the typically longer times (up to 300 s) used in other references²³⁻²⁵. These settings allowed the detection of elements of atomic number 13 (Al) or higher. The settings also provided a sufficient raw count rate (range 50.000-110.000, avg. 90.000) to acquire good spectra without saturating the detector (saturation occurs over 125.000 counts).

2.4 FORS, Fiber Optics Reflectance Spectroscopy

A FORS^{26,27} system was also used to complement the MSI and XRF analysis. It is composed of 4 Ocean optics elements; the light source, the spectrometer, the probe and the two fiber optics. The light is provided by a halogen lamp HL-2000-FHSA, with output power 7 W and color temperature 2960 K. The USB4000 spectrometer features a 3648-element Toshiba linear CCD array, a diffraction grating with a working range of 360-1000 nm and resolution 1.5 – 2.3 nm (FWHM). Spectra have been acquired with the following parameters: integration time: 5 s (integrating sphere), 5 ms (reflectance probe), scans to average: 4, boxcar width: 5. As a probe, was used the integrating sphere ISP-R which averages the diffused and the reflected components, providing a spectrum which is characteristic of the material analyzed and does not depend on the specific measuring angle.

3 Results and Discussion

3.1 Mapping Retouchings

It is often necessary to select areas of interest, sometimes simply to highlight them in condition reports. However, it might be even to measure their area, such as to estimate the time needed for a cleaning intervention, or to know the percentage of the original work surviving. The process of partitioning a digital image into multiple segments is called segmentation. This task can be accomplished manually or it can be automatized with Photoshop tools. The selections can be saved and recalled for a number of useful applications in art conservation and documentation. The UVF image makes the retouched areas visible. They do not emit any fluorescence under UV light and appear as characteristic black spots surrounded by the original paint, which is strongly fluorescent^{15,16}. The contrast is so intense, suggesting that the automatic segmentation should be successful. The following are illustrated steps to perform this segmentation task. It must be pointed out that highly compressed images cannot provide accurate results and therefore it is necessary to work with an uncompressed format such as TIFF.

3.1.1 Choosing RGB Channel

It is recommended to use only the B (blue) channel of the UVF image since the tonal differences between the retouchings and the original paint and varnish are stronger. This effect is

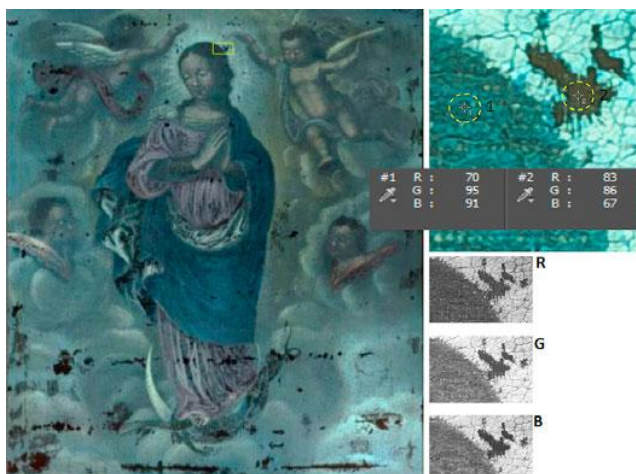


Figure 2: Madonna and four Angels. Left, position of the detail; Right down, RGB channel images; Right up, RGB image with RGB values for spot 1 and 2.

due to the fact that the UV fluorescence occurs mostly in the blue region of the spectrum. Figure 2 shows the RGB values of the UVF image for spot 1, on the hair of the Madonna and four Angels, and for spot 2 on the retouch. The INFO panel shows that the tonal difference is greater for the B channel. The paint used for the hair is pretty dark and its tone is close to that of the retouch, hence the need to choose the B channel where the tonal difference is higher in order to enhance the quality of the segmentation.

3.1.2 Flatfield correction

In order to enhance the success of the segmentation, the image should be evenly illuminated, so that the tone of the retouches is the same across the image. Unfortunately this is not possible with most of the UV sources and in any case it was not the case for this UVF image, which was acquired using a spotlight source. Even if the image was evenly illuminated, it should also be taken into account that imaging devices and lenses may introduce vignetting. Furthermore, the strong fluorescence of bright paint affects the tone of the retouches nearby. This can be easily verified by placing Color Sampler points on retouches close to bright or dark paint. Consequently, flatfield correction for uneven illumination is almost always necessary. In microscopy it is common to save a flatfield image and use it for the correction, in the case of UVF photography this is not possible but instead a duplicate of the UVF B channel image can be used to create the flatfield correction image by treating it with the Gaussian Blur

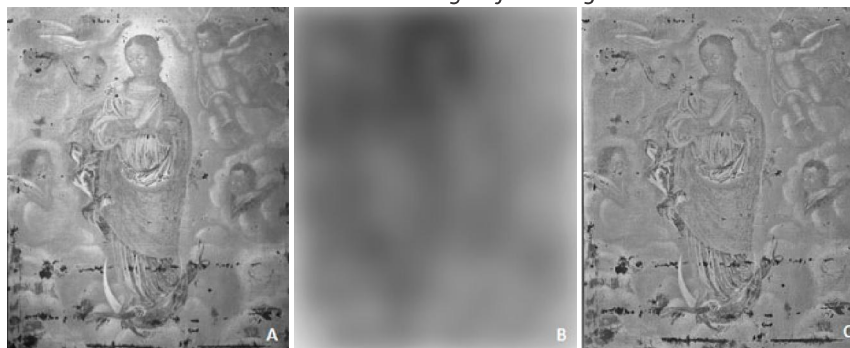


Figure 3: Madonna and Four Angels. A) Original UVF B channel image; B) Flatfield correction image, blurred and inverted; C) Flatfield corrected UVF B channel image.

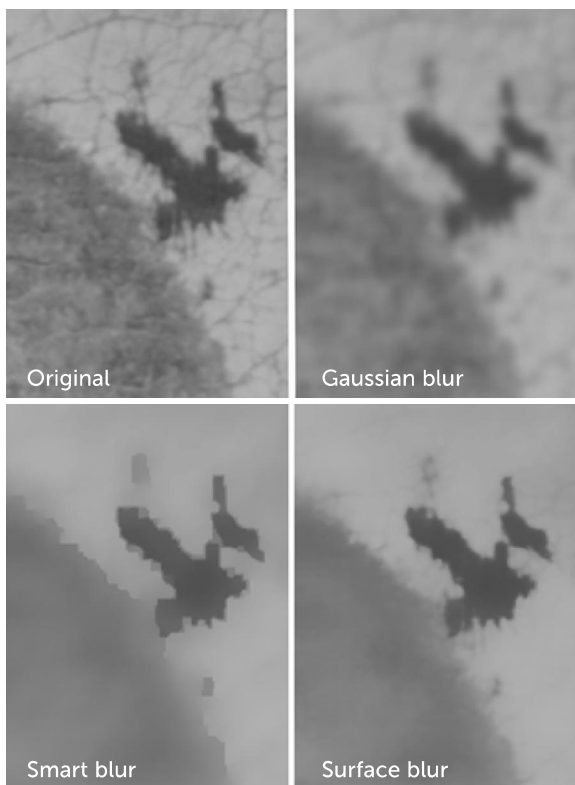


Figure 4: Madonna and four Angels. UVF B channel image. Original image and the image blurred with 3 different Photoshop blur tools.

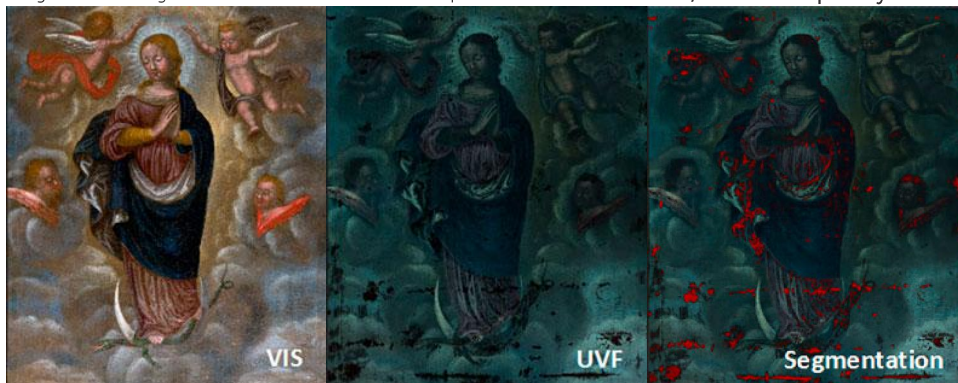


Figure 6: Madonna and four Angels. VIS, UVF, and the segmented UVF image.

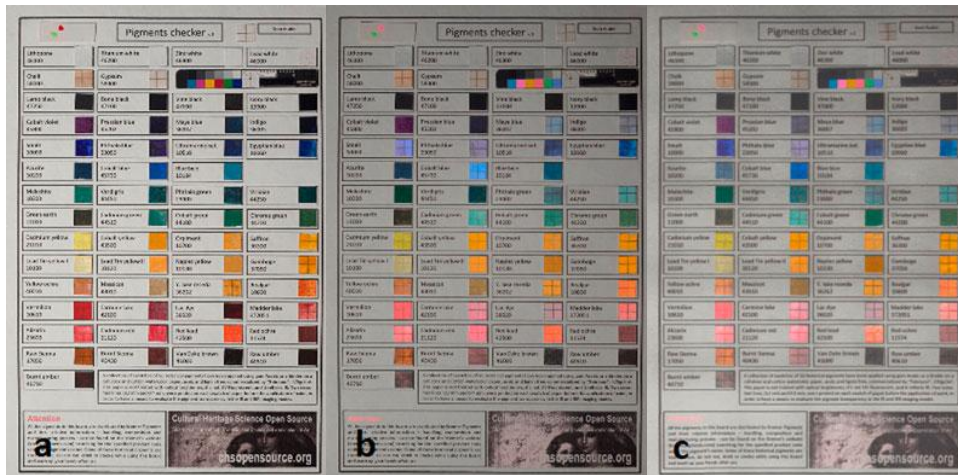


Figure 7: Pigments checker. VIS, IR and IRR images blended with luminosity mode.

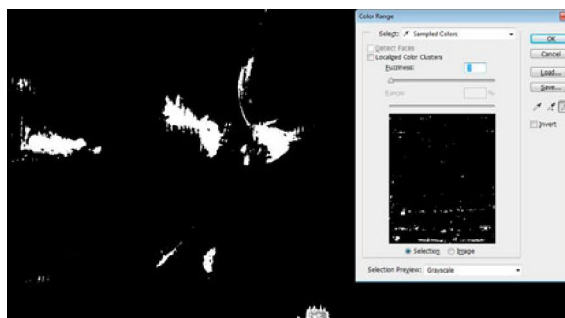


Figure 5: Madonna and four Angels. A useful full window preview of the segmentation (white pixels) is possible within the Color Range tool.

filter (radius = 100 pixels) and inverting it in order to create a negative image of the original. This flatfield image is placed as a layer over the original image and then blended with Hard Light Mode and Opacity 30% or any other value, so that the color sampling points - that have been placed at the beginning of the process on the retouches - read values as close as possible to each other, Figure 3.

3.1.3 Blurring

The flatfield corrected UVF B channel image is further edited with a blur filter in order to eliminate the noise represented by the extensive craquelure on the painting. The cracks lack paint and the fluorescent old varnish, and consequently their tone is close to that of the retouches. If untreated, they would generate a number of false segmentations. Craquelure can be easily attenuated applying a blur tool thanks to its characterizing thin-line shape. The Gaussian blur filter is the most known but the least effective since it blurs indistinctly the noise and detail without distinction. More specific are the Smart Blur and the Surface blur tools. Both have advanced controls to perform more precise blur. The Surface blur filter is preferred for this specific task because it blurs while preserving the edges, Figure 4. Another reason to blur the image is to average the pixels of the darkest pigments which otherwise will provide false segmentations.

3.1.4 Segmentation

Color Range is a powerful selection tool for the segmentation of retouches. It analyzes the luminance of the image and selects tonal ranges within a single color or tonal ranges in grayscale chosen by the operator. Color Range is used as the popular *magic wand* but it makes the selection dynamic and shows a full preview. So it is possible to choose the best FUZZINESS value for the specific task, as opposed to just trial and error, like with the *magic wand* tolerance bar, Figure 5. The best procedure is to set FUZZINESS = 1 and proceed by adding or subtracting the tones until the selected areas represent sufficiently the retouches in the full preview, Figure segmentation. The selection can be saved as an alpha channel and manually edited using the brush tool to refine the selection.

3.1.5 Calibrating and Measuring retouchings

The final goal of the segmentation is to measure the total area occupied by the retouches and, therefore, the image must be calibrated using the *Set Measurement Scale* tool. Art documentation photography always includes a color checker that has a measurement scale which can be set as the scale for the calibration. Otherwise, if the size of the painting is known, one of the sides can be used for the calibration. Once the segmentation is active, the *Measurement Log* tool provides the total area as well as other geometrical parameters. For the Madonna and four Angels painting, which measures 60 x 75 cm, the retouched area was found to be 228 cm² (0,05%), Figure 6.

3.2 Paint and underdrawing

The usefulness of blending the VIS and IRR images has already been proposed 28. It helps to better understand the underdrawing in relation to the actual painted Figureures, and to compare a painting with the

under paints, highlighting changes between the original composition and the final version. The Luminosity mode blends the brightness (luminosity) values while ignoring the color information. In an infrared image (IR and IRR) we are interested in the contrast between the white ground and the black drawing. IR and IRR are gray scale images. Figure 7 shows the IR and IRR images blended with lumosity with the VIS layer for the pigments checker and Figure 8 shows as an example the red ochre. The colored IR and IRR images preserve the information on the underdrawing.

Another example on a mock up is provided by the painting, Madonna and Child, Figure 9. The underdrawing, visible in the IR and IRR, is blended with the color information without losing quality. While, an example on an actual work of art is the Sicilian cart piece, which shows an extensive underdrawing, Figure 10.

3.3 Color mapping cadmium pigments

The Luminosity blending mode can be used to enhance features of monochromatic MSI images while preserving the colors of the VIS image. This is useful to give a more intuitive reading when examining IRF images. Egyptian blue is found in archaeological art-

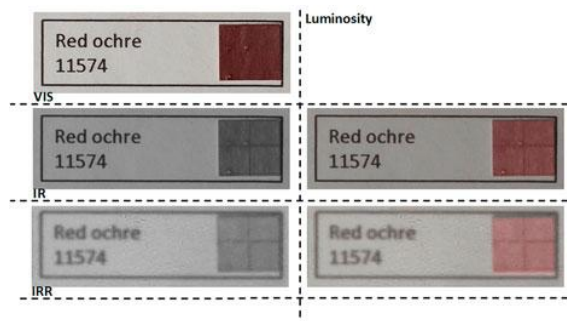


Figure 8: Pigments checker. VIS image (a) and Luminosity blending of the IR (b) and IRR (c) images of the red ochre swatch.

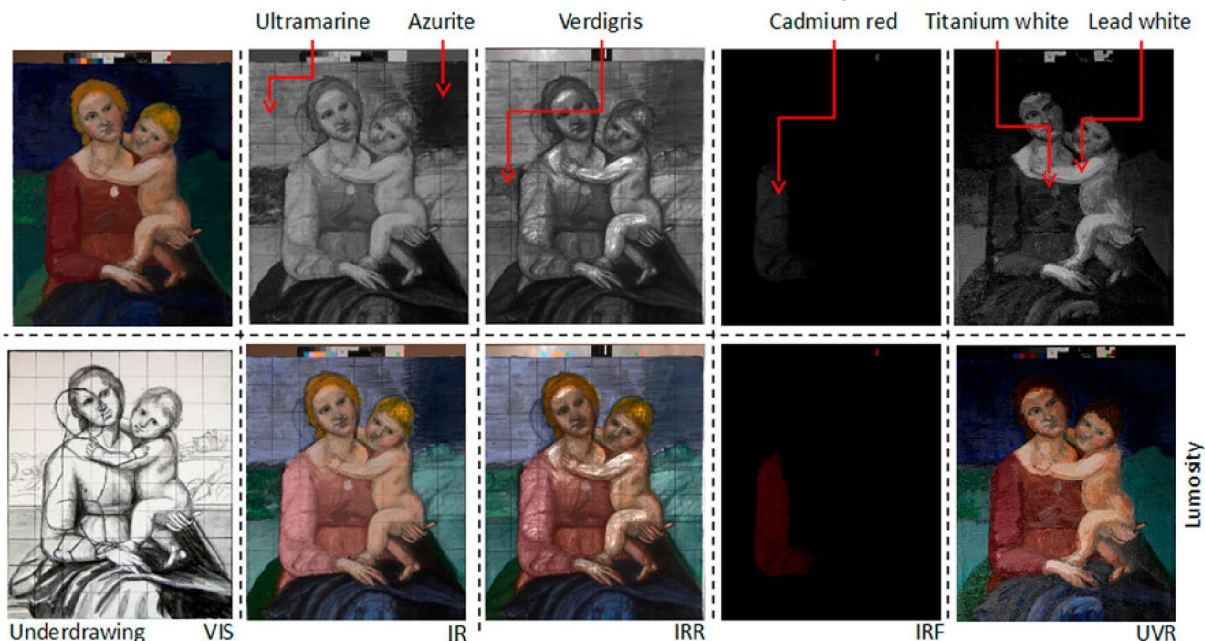


Figure 9: Madonna and Child, Luminosity blending of VIS image with IR and IRR. Bottom left, photo of the underdrawing before being painted over.

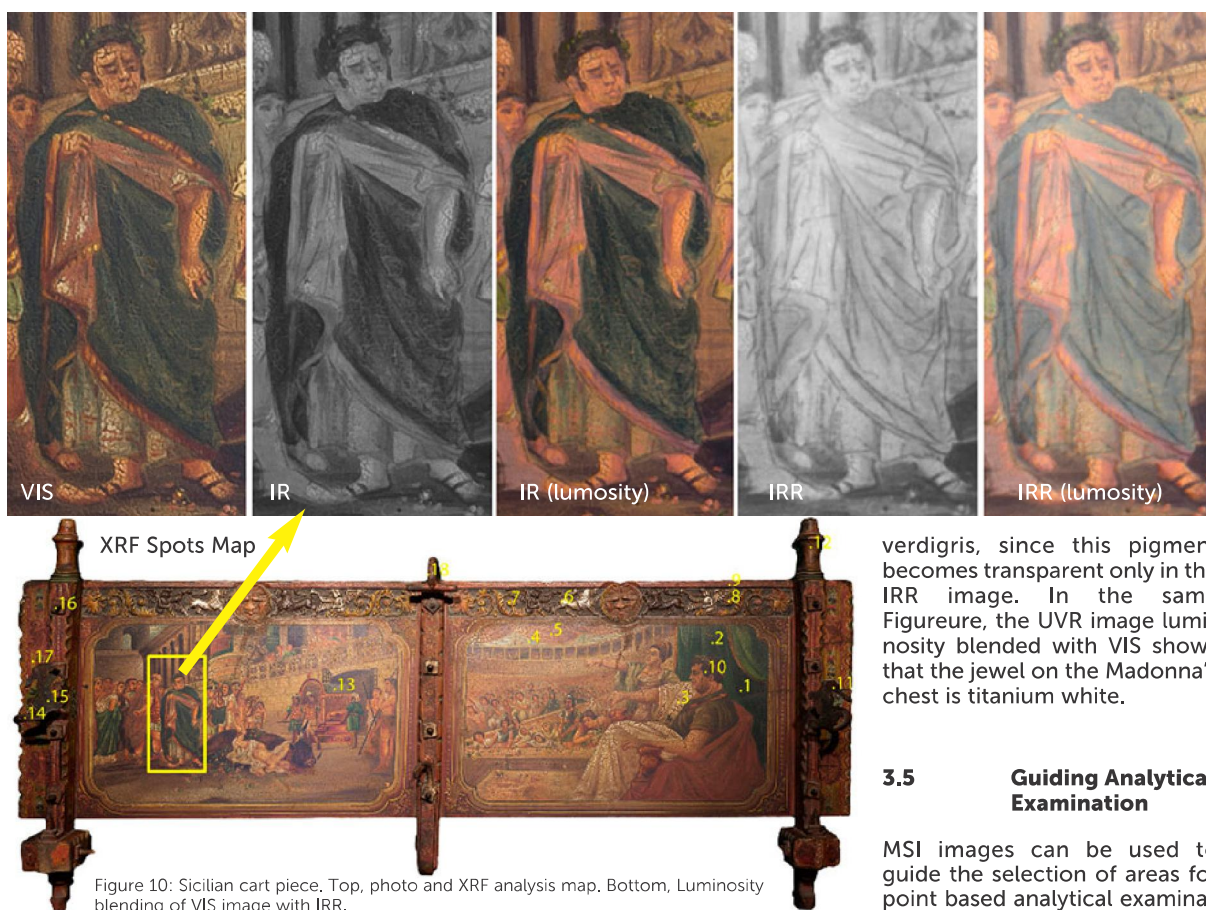


Figure 10: Sicilian cart piece. Top, photo and XRF analysis map. Bottom, Luminosity blending of VIS image with IRR.

works and since it is the only pigment known to the old world that shows infrared fluorescence, its identification doesn't pose any problem. On the other hand, cadmium pigments could be red, green and yellow and are all IR fluorescent and common in modern art. The gray scale IRF image shows the position of these materials but no information about their visible color. The Luminosity blending mode allows us to see the visible color of the four IR fluorescent cadmium pigments in the pigments checker, Figure 11. Analogously, the right sleeve of the Madonna and Child's shirt is cadmium red, Figure 9 as well as the red cloth of the upper left angel in the Madonna and four Angels, Figure 12.

3.4 Pigment Identification

While MSI is not sufficient for the outright identification of pigments, it is useful to locate retouches or paint using different pigments to achieve the same tone. Indeed, different pigments that have the same color in the VIS image can often be distinguished by reading the UVR image, as well as UVR, IR and IRR. Two or more of the monochromatic MSI images can be *Luminosity* blended with the VIS layer to show that the pigments are different. For example, the white pigments Titanium white and zinc white are dark in the UVR image as opposed to lithopone and lead white, Figure 13. In the Madonna and Child, the IR blended with VIS in luminosity mode allows us to distinguish ultramarine from azurite, Figure 9. Comparing the IR and IRR, after both having been luminosity blended with VIS, allows the detection of areas painted with

verdigris, since this pigment becomes transparent only in the IRR image. In the same Figureure, the UVR image luminosity blended with VIS shows that the jewel on the Madonna's chest is titanium white.

3.5 Guiding Analytical Examination

MSI images can be used to guide the selection of areas for point based analytical examination. They represent a valuable timesaving tool that allows for a preliminary assessment to determine which areas seem to have been painted with the same pigments and any "interesting" points or outliers that warrant further investigation. The infrared false color (IRFC) image is particularly useful as a starting point, because it combines visible data with IR transparency information and in certain cases can easily parse different pigments that appear similar to the naked eye²⁹. After observations are made by analyzing the Photoshop processed MSI images, a reasonable number of points may be selected for analysis by XRF. In most cases, the XRF can make a final confirmation on the pigment ID for the primary material used. However, in certain other cases it instead serves only to rule out pigments containing a base of transition metals if these are not found to be present in the spectra. In the case of the Sicilian board in Figure 10 the MSI shows an interesting green. It was analyzed with XRF (point 1) and showed a high chrome content (Table 1). This suggests chrome green or a mixture of chrome yellow with a blue pigment. This second hypothesis seems more likely because this green paint absorbs the IR, while chrome green is almost transparent in the IR. Furthermore, chrome yellow was found (point 17). Also the high content of lead confirms this assignment - chrome yellow is lead(II) chromate (PbCrO₄). The green paint is characterized by its opacity in the IR and the fact that it becomes transparent in the IRR, Figure 10. These features can be used to check if other green pigments or mixtures are used throughout the artwork. The red paint doesn't show any difference in the MSI images and so it was analyzed only in 3 representative points, on the frame (point 9), on the metal decoration (point 11), and on the painting (point



Figure 11: Pigments checker. Blending of VIS and IRF images with the Luminosity blending mode.

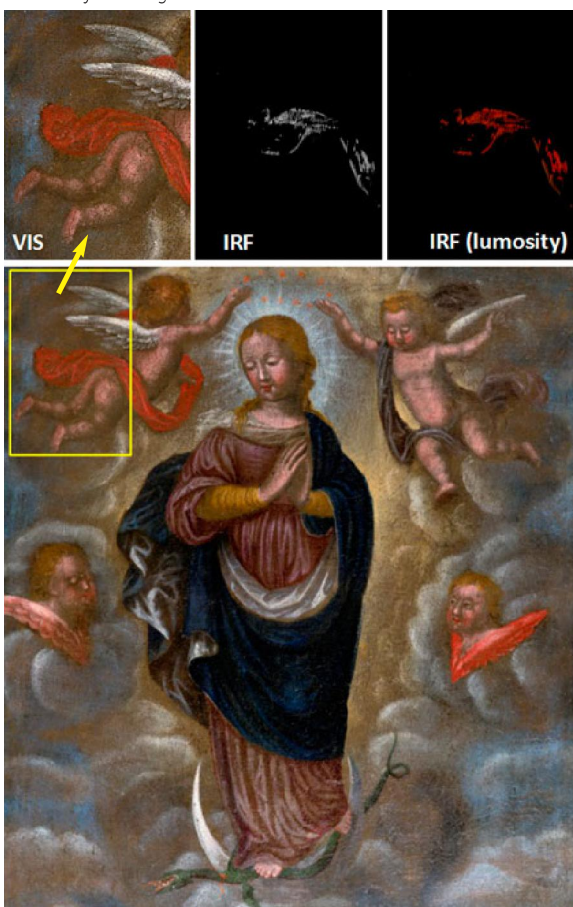
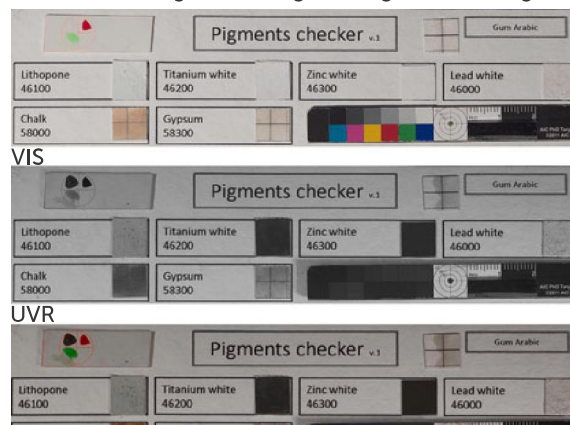


Figure 12: Madonna and Four Angels. Blending of VIS and IRF images with the Luminosity blending mode.

5). They all have a presence of Hg, consistent with vermilion (HgS), which is also suggested by the FORS spectrum, Figure 14. The same type of deduction, using information from these complementary techniques can be done with the other colors.

4 Conclusions

The Photoshop tools that separate relevant features from the background (segmenting) are among the



UVR (Luminosity)

Figure 13: Pigments checker. Blending of VIS and UVR images with the Luminosity blending mode.

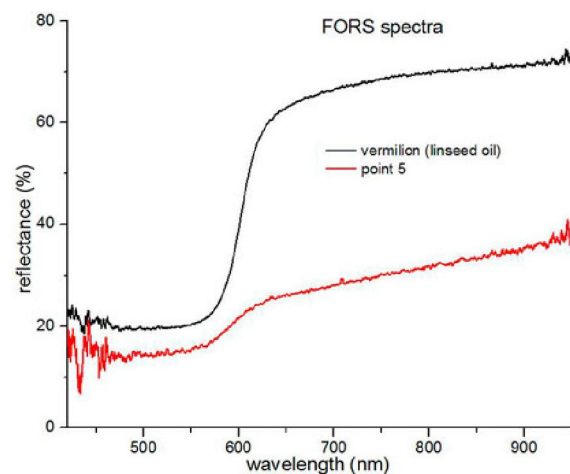


Figure 14: FORS spectrum of point 5 compared with vermilion.

Spectrum	Element	S	K	Ca	Cr	Fe	Cu	Zn	Sr	Ba	Ba	Hg	Hg	Pb	Pb
	Line	K12	K12	K12	K12	K12	K12	K12	K12	K12	L1	L1	M1	L1	M1
	Energy/keV	2.309	3.314	3.692	5.415	6.405	8.046	8.637	14.165	32.194	4.466	9.989	2.195	10.551	2.342
Cart 1	green	28649	5071	124327	51366	620827	23326	977292	13023	914	116240	75359	8250	540936	12922
Cart 2	green	50199	5853	126334	79823	208274	10379	787656	17727	557	54376	65138	4969	1012777	20834
Cart 4	blue	76202	3103	65798	7931	120682	20206	603131	17590	898	43615	93322	7529	1397719	16403
Cart 5	red	61862	2290	89775	8380	235525	13890	538943	18297	889	31818	117849	7004	1526539	15817
Cart 9	red	34982	7749	120659	45440	122413	8776	152996	38097	2122	128816	159575	5391	1469097	19643
Cart 11	red (on metal)	415	24033	248770	15066	642368	892707	1088932	12031	1822	159181	113361	9278	384143	12227
Cart 13	blue	59904	2369	101403	17217	218739	26361	1101272	19675	1077	116893	87451	9102	839916	14831
Cart 17	yellow	9672	1768	32148	12696	27935	3648	217180	11356	790	46282	34737	2025	641117	8340

Table 1: Selected XRF spectra peak integrations from the Sicilian cart piece complement the MSI interpretation, showing elemental compositions for pigments present in the work.

most powerful and yet less known capacities that this software offers. The use of these tools can produce results comparable with those of much more expensive scientific software. The segmented features can be measured for a number of different applications useful for the workflow of art documentation. Although, quantitative and accurate, it must be pointed out that it is not possible to obtain exact segmentation and therefore, precise measurements. On the other hand, these tools are useful for enhancing the workflow in the estimation of the extension of losses, such as for the preparation of condition reports. The segmenting methods also reduce user intervention and potential bias. In the case that the segmentation has to be more precise it is always possible to add further manual editing. The selection can be corrected manually. Photoshop also has useful tools for the visualization of the information of MSI layers, such as the luminosity blending mode, which enhances the reading of infrared images and can guide the selection of areas for point based analytical examination, saving time by determining areas which were not painted with the same pigments.

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