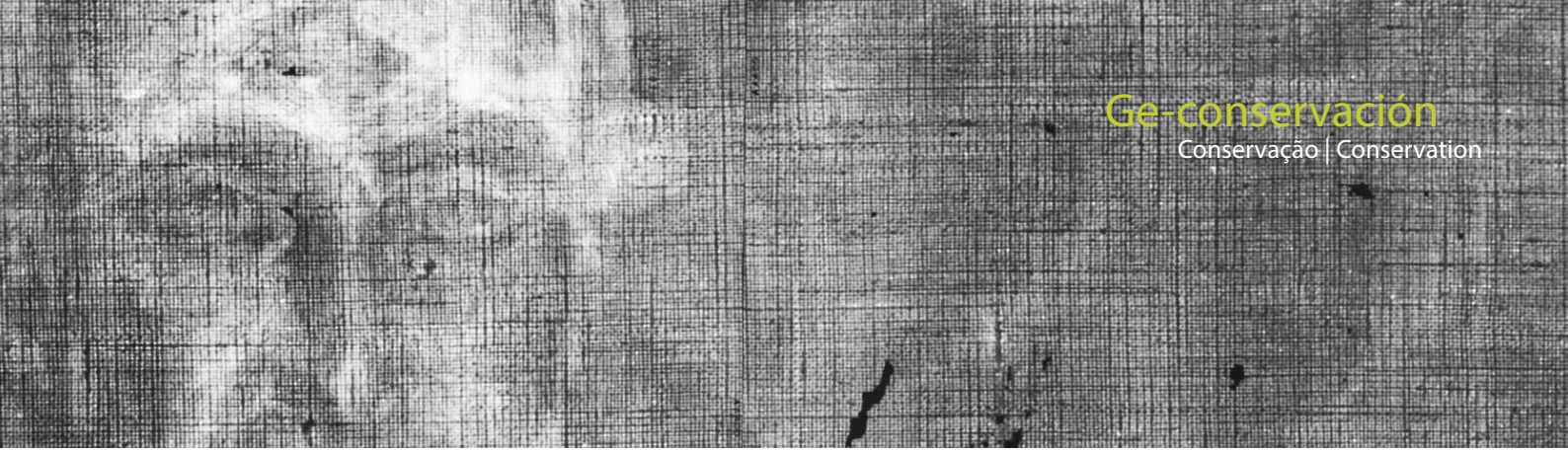

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Multi-band technical imaging in the research of the execution of paintings. The case study of the portrait of Carlos IV, by Francisco de Goya

Miquel Angel Herrero-Cortell, Marta Raïch, Paola Artoni, Isidro Puig

Abstract Multi-band technical imaging (MBTI) is widely used as an established method for art examination. Although the diverse techniques that are employed have their own specific importance, if the many results in experimental hybrid images are confronted with one another they provide much more information. The main objective of this paper is to show the usefulness of the technique for a holistic understanding of a portrait of the King Carlos IV. More specifically, MBTI is intended to help in the reconstruction of the artist's painting process, by revealing physical traces of the creation and execution of the portrait (ductus and brushstrokes, alterations, underdrawing and staining, pictorial composition process, changes and Pentimenti, inpaintings, pigment identification, etc.). For this case study, such information is necessary to delve into the painter's work process, revealing some characteristics that make it unique, finally allowing the proper identification and attribution of the portrait.

Palabras clave: multi-band imaging, technical photography, IR imaging, UV imaging, X-Ray imaging, reconstruction, Goya, painting

Imagen técnica multi-banda en la investigación del proceso de ejecución de las pinturas. El caso del retrato de Carlos IV, de Francisco de Goya

Resumen: La imagen técnica multi-banda (MBTI) es ampliamente utilizada como un método eficaz para el examen de obras de arte. Aunque las diversas técnicas que lo conforman tienen una entidad propia, cuando se usan juntas proporcionan mucha más información al confrontar los diversos resultados. El objetivo principal de este trabajo es mostrar su uso en comprensión material, procedimental y creativa de un retrato del Rey Carlos IV. Más específicamente, la imagen técnica multi-banda se ha utilizado aquí para ayudar en la reconstrucción del proceso pictórico, al revelar datos relacionados con la creación y ejecución del cuadro (ductus y pinceladas, alteraciones, dibujo subyacente y primer manchado, composición pictórica, cambios y arrepentimientos, repintes, identificación de pigmentos, etc.). En este caso de estudio, dicha información sirve para profundizar en el proceso de trabajo del pintor, revelando algunas características que lo hacen único, y permitiendo finalmente la correcta identificación y atribución del retrato.

Keyword: multi-banda, fotografía técnica, imagen infrarroja, fotografía ultravioleta, radiografía, reconstrucción, Goya, pintura

Imagem técnica multi-banda na investigação do processo de execução das pinturas. O caso do retrato de Carlos IV, de Francisco de Goya

Resumo: A imagem técnica multi-banda (MBTI) é amplamente utilizada como um método eficaz para examinar obras de arte. Embora as várias técnicas que o compõem tenham a sua própria entidade, quando usadas em conjunto, fornecem muito mais informações ao confrontar os vários resultados. O principal objetivo deste trabalho é mostrar o seu uso na compreensão material, processual e criativa de um retrato do Rei Carlos IV. Mais especificamente, a imagem técnica multi-banda tem sido usada aqui para ajudar na reconstrução do processo pictórico, ao revelar dados relacionados com a criação e execução da pintura (ductus e pinceladas, alterações, desenho subjacente e arrependimentos, repintes, identificação de pigmentos, etc.). Neste estudo de caso, esta informação serve para aprofundar o processo de trabalho do pintor, revelando algumas características que o tornam único, e, permitindo, finalmente, a correta identificação e atribuição do retrato.

Palavras-chave: Multi-banda, fotografia técnica, imagem infravermelha, fotografia ultravioleta, radiografia, reconstrução, Goya, pintura

Introduction

Between 2013 and 2016 the CAEM of the University of Lleida[1] studied a painting of Carlos IV that had been historically considered by some authors a probable copy by Agustin Esteve or another of Goya's pupils following a model executed by the master). The portrait is 111'5 cm x 76'5 cm, painted in oil on canvas, it depicts the king dressed for his coronation ceremony, and is now convincingly attributed to Goya [figure 1]. The CAEM team began multidisciplinary research that included diverse approaches: a documentary-historical study aimed at delving into the past of the work, its provenance; iconographical and formal analyses, which intended to understand uninvestigated aspects like the strange sash worn by the king or the lack of the Golden Fleece; a scientific study, which implied several physical and chemical analyses, as well as a procedural and technical one, focusing on understanding the materiality and the keys of production of such portrait (Puig *et al*. 2016). It was a long interdisciplinary research project that involved several teams of professionals (art historians, historians, restorers, curators, *connoisseurs*, and other professionals) from many national and international universities, museums, and research centres; it was funded by an anonymous donor. Among the many technical examinations which were carried out on the painting[2], a multi-band technical imaging analysis in several spectral bands was commissioned to us, and performed to understand the materiality of the painting and the way in which it was executed.

The main objective of this article is to show how several technical images shot in different wavelengths of the electromagnetic spectrum are useful for a holistic understanding of the aforementioned painting and, more specifically, for the reconstruction of the painting process and its evolution. With that aim, multi-band technical imaging analysis (MBTI) reveals facts related to the creation and execution of the painting (*ductus* and brushstrokes, alterations in the support and the colour layers, underdrawing and first staining, pictorial composition process, changes and *pentimenti*, inpaintings, pigments identification, etc.). For this specific study case, such information is necessary to delve into the painter's work process, revealing some characteristics that make it unique.

Figure 1- (a) Francisco de Goya. *Portait of Carlos IV* 1789. Oil on canvas, 111,5 x 76,5 cm, private collection. Since 2017 temporarily ceded to the Museo Goya - Fundación Ibercaja, Zaragoza, where it is currently displayed. (b)VIS detail of the face.

Materials and methods

Multi-band technical imaging (sometimes mistakenly called 'multispectral' or 'hyperspectral') is widely used as an established method for art examination (Pelagotti *et al*. 2008:27-36); (Cosentino 2013); (Cosentino *et al*. 2014: 7); (Pamart *et al*. 2017: 559)[3]. It is an extension of technical photography (TP) in different bands of the spectra. Although the diverse techniques which MBTI comprises have their own independent value, when they are used together they provide much more information, by comparing the many results [figure 2]. In brief, in addition to the visible images (visible VIS, racking light RL and Transmitted Light TL, common in TP), IR, UV, and XR bands are also considered. Ultraviolet fluorescence (UVF) is used to map the retouches that appear dark under UV light. It allows the observation of additions and inpainting as well as the layers of varnish, and it finally serves to register the fluorescence of matters (Rorimer 1931); (Warda *et al*. 2011); (Cosentino 2015 e: 58), while ultraviolet reflected (UVR) is recognized only as a useful tool to identify white pigments (Cosentino 2015 e: 21). Infrared imaging (IR), and reflectography (IRR) aim at the visualization of the underdrawings and *pentimenti* (Van Asperen 1969); (Poldi; Villa 2006:37-126); (Bonano *et al.* 2017), (Marilena [*ed.*] 2017). Infrared transmitted (IRT) reveals also the construction process, showing also underdrawing, underpainting and pentimenti (Motsatsou *et al*. 2011), while infrared fluorescence (IRF) is used to detect certain pigments (mainly those that are cadmium based). Finally, all the methods together can be used for the tentative identification of pigments (Cosentino 2014 b; 2015 d), being the infrared of false colour (IRFC, a postproduced image by blending VIS and IR) the most useful technique for the same purpose (Poldi; Villa 2006: 127-137). To complete the spectrum, X-Ray imaging (XR) becomes the main tool, specifically to confront the results of the aforementioned techniques (Gabaldón 1999: 27); (Poldi; Villa 2006: 173-196).

VIS, IR, and IRT were carried out twice, using two different devices: first with a *Sinarback® eVolution 75h*, (Infrared-Head) HD camera (33 MP, Dalsa FTF 5066 C, CCD sensor RGB Mosaic Filter), and then with a *Nikon® D7200 DSLR* (24 MP, CMOS sensor) digital camera modified "full spectrum" (sensitivity between about 360 and 1100nm), provided by CHSOS[4]. The filter used in the Sinarback Camera was Hoya RM100 Infrared Filter 49 mm, while for the Nikon filters were: a) For Reflected Ultraviolet (UVR) photography, B + W 403 filter plus X-Nite CC1; b) For Visible (VIS), racking light (RL) and Transmited Light (TL) photography, X-Nite

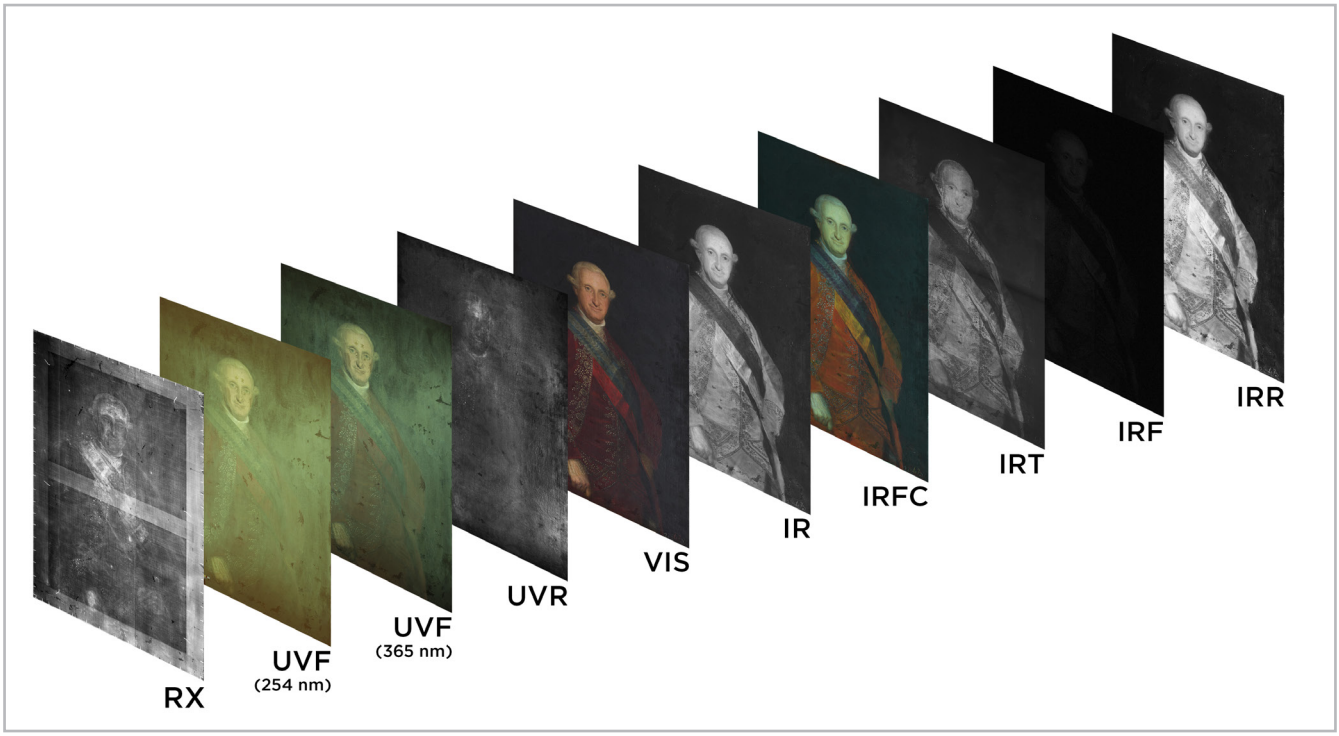

Figure 2- Series of technical images at different wavelength points on the electromagnetic spectrum, making up the present multi-band analysis carried out over the Carlos IV portrait by Francisco de Goya

CC1; c) For UV Fluorescence (UVF365 nm and UVF254 nm) photography, B + W 420 plus X-Nite CC1; d) For Infrared (IR), Infrared Fluorescence (IRF), and Infrared Reflectography, Heliopan RG1000, like the one described in other papers (Cosentino, 2015 a, 2014 b, 2015 d). Two halogen lamps (1250W) were used for VIS, IRR, and IR imaging while UV high-Flux 365nm LED (filtered with UV-pass glass) provided by CHSOS was used for UVF and UVR photography. UVF254 was performed with a 254nm UV lamp, Spectroline MiniMAX UV-5F (5W lamp complete with UV-pass glass). A CHSOS white light LED lamp filtered with the X-Nite CC1 was used for IRF imaging. The American Institute of Conservation Photo Documentation (AIC PhD) target was used for calibration of the technical photos. The images were shot in RAW mode and then color corrected, balancing white by using the N8 neutral grey patch in the AIC target[5]. They were also exposure corrected: N8 patch 150 +/- 5 for VIS. The same patch was also used for correcting the other images: 100 +/- 5 for IR and IRR, and 50 for UVR. The AIC PhD target was modified by CHSOS coupling 3 UV activated emitters: a section of a card for forensic UV photography (orange fluorescence), a swatch of zinc white (yellow fluorescence), and a fluorescent paint (green fluorescence). These 3 UV emitters together with the red fluorescence emission of the red square of the AIC PhD target itself are used for color balancing of UVF and UVF254 photos, (Cosentino 2015 d: 290) an OSIRIS® (*Opus Instruments*, 16 MP, InGaAs line sensor) camera featuring an internal mechanical scanning system to create high-quality images using a leading InGaAs line sensor was used to perform infrared reflectography IRR (Bonano *et al*. 2017:32). The X-Ray imaging was carried out at the CRBMC in Valldoreix (Barcelona), using a Yxlon powered by Comet 320kV tube. The film used was *Kodak® Industrex MX 125* with Pb screen. The XR image was digitalized with an Array Corporation Scanner, at a resolution of 50 microns. Exposure parameters were the following: Power=40 kV; Intensity=2,5 mA; Focus 3,6; Time 2' 30"; distance 1,5 m.

In order to compare with other cases, some other copies of the same model (also attributed to Goya or to Esteve) have been studied with HD IR imaging with the Sinarback camera; these works are: the portrait preserved in the Fundación Lázaro Galdiano, attributed to Augustine Esteve; the royal couple owned by the Fundación Altadis of Sevilla; the portrait of the Monarch owned by the Diputación of A Coruña, currently deposited in the Palacio de Rajoy of Santiago de Compostela (City Hall); another pair formed by the portrait of Carlos IV in the Museo de Bellas Artes of Asturias (Oviedo); and the one of the Queen preserved in the Museo Ibercaja Camón Aznar, in Zaragoza; as well as several copies kept in private collections all over Spain (Puig *et al*. 2016).

Results and discussion

—Multi-band results

Visible imaging, raking light, and transmitted light (VIS, RL, TL) were carried out as part of the common TP, used mainly to document the painting condition. In addition, a PCE-200 electronic USB endoscope (60-200X) was also used to examine the surface, helping in the organoleptic characterization. While VIS imaging documents the visible and lets us compare several details between different

Table 1-. The table compiles the different technical images of the MBTI carried out on this painting, as well as several aims of study with the results obtained for each one of them. Green cells correspond to an excellent result was achieved for that purpose, while yellow cells correspond to a partial result. When all the techniques are applied and compared, there can be a more precise interpretation of the procedural, technical and material facts.

Table 1. List of the MSI analysis carried out on the Carlos IV portrait case study, and the utility of the results							
Technique	*Ductus*/Brush -strokes	*Pentimenti*	Underdrawing	Pigments visual identification	Inner condition	Superficial condition	Inpainting
VIS		-	-	-	-		
RL			-	-			-
TL			-	-			
UVF 355	-	-	-		-		
UVF 254	-	-	-		-		
UVR	-	-	-		-		
IR	-					-	
IRFC	-					-	
IRF	-	-	-		-	-	-
IRR	-					-	
IRT	-					-	
XR			-			-	-

copies, it serves also in the production of IRFC images, but no major contribution to the MBTI may be highlighted for the rest of the visible techniques [table 1].

Starting with the evidence shown by the MBTI, it must be highlighted that UVF (254 and 365 nm) was especially necessary for the observation of the condition of the painting: minor retouches here and there, and a thick layer of old greenish fluorescent varnish were found. The fluorescence of the white pigment made the use of lead white easily identifiable. A certain orange fluorescence was found over the red jacket, being clearly more visible at 254 nm rather than 365nm; this suggested the presence of a madder lake used in glazes for achieving red shade tones (Cosentino, 2014 b: 10), (Pinna, *et al*. 2009: 96) and was also confirmed later by IRFC. UVR was done in order to try to map possible titanium or zinc white inpainting (Cosentino 2014: 7; 2015 e: 58), although no significant results were obtained for both pigments, and only a few tiny spots indicated the potential presence of one of these pigments. Even with the aim of mapping eventual retouches of cadmium red over the jacket, an IRF was carried out, with a negative result, obtaining a completely black picture, in which only the cadmium square of the CHSOS modified AIC target emitted fluorescence, evidencing that although some minor restoration had been performed on the canvas, none of the cadmium pigments had been used (Cosentino, 2014: 9; 2016: 5).

Among all the technical images, those on the IR side have been the richest in terms of useful information. Infrared imaging family (IR, IRR, IRT, IRF, IRFC), by being the wider one, helps us to understand the painting technique and the creative processes from many approaches by revealing the hidden sketching or brushstrokes that at first sight are not visible (Cosentino 2016). They complement perfectly and match VIS, UVF, UVR, and especially XR. The IR family showed important modifications or *pentimenti*, which could be the key to fully understanding and interpreting this artwork; amendments that, in our opinion, are highly significant due to the unique and singular value of this painting.

Ordinarily it is well understood that a copy or replica of the king's portrait should be as accurate and as close as possible to the original prototype previously chosen and established, which is not a difficult or an overly complicated exercise. By the use of a simple grid the accuracy and plausibility regarding a previous model can be fully secured. This means that the kind of drawing lines that can be found when we are dealing with a copy (either the tracing or grid-drawing) replicates the configuration of a previous work. However, it is illogical to find substantial *in itinere* modifications or positional changes. *A priori*, therefore, any modification should be ascribed to the original prototype, that is, the first version of a three-quarter-length portrait of King Carlos IV performed by Goya. This original version would display various logical variations in order to find the position and desired composition both by the artist and the patron. MBTI techniques of imaging reveal unique facts: the repositioning of many elements in the picture and clear *pentimenti* can be observed, unsuitable aspects for a copy. If we also take into account that the final configuration chosen for the canvas is exactly the same that is repeated in other portraits of the same series, one might ponder over the purpose of the changes of the underlying layers.

A simple glace at IR and IRR [figure 3] evidences some pentimenti or modifications, which are especially

Figure 3- (a) IR at 1.050 nm and (b) IRR (1.100-2000 nm). Some *pentimenti* are noticeable in both images. The repainting of the Sash of the Order of Carlos III can be observed together with the changes of position of the other two sashes and the posture of the Monarch's arms. The variations in the grey of the blue sash is due to its' content of Prussian blue, much clearer in IRR.

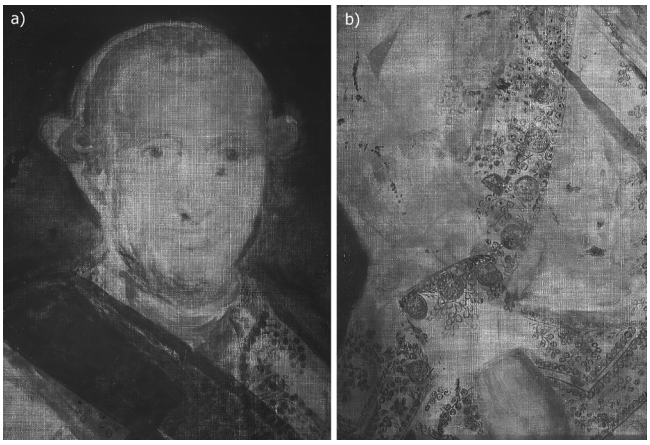

Figure 4-. IRT (1.050 nm) allows us to appreciate in a clear way the weave of the canvas, some of the traces of the underlying preparatory drawing, the wash-sketch composition of the figure. (a) The head shows some *pentimenti*. It can be appreciated how nose and eyes were almost in a frontal view, and how the head's profile was modified. However, neither IR nor IRR allow us to appreciate the aforementioned technical procedures. (b) Detail of the area of the monarch's waist, where we can appreciate the right hand, as well as the previous outline sketch located above it, displaying the cuff and the three circular motifs of its edge. The original angle of the arm was obviously modified, like the dark triangle on the upper left corner suggests.

noticeable on the left arm of the King, his elbow, and his shoulder. The position of the sashes seems to have been modified and an almost imperceptible hidden hand emerges very tenuously over the waist.

Thanks to the IRT a subtle composition drawing can be observed, probably made by a graphite or lead tip. It is not a continuous and ubiquitous drawing (actually it can only be appreciated in a few areas of the canvas), but rather a trace of small lines that the painter used for an accurate positioning of the main features of the monarch. Consequently, we can clearly visualize the outline of the eye sockets, the head, and the right shoulder. In addition, IRT shows the way the physiognomic composition was performed with dissolved oil painting (commonly known as a wash composition sketch). It can be appreciated, in the rendering of the mouth, nose, eyes, and in the monarch's outline [figure 4]. Actually, this preparatory sketch turns out to be the main composition of the work, whilst the line drawing is relegated to a mere initial spatial location. This fact confirms that the painting technique was a quite direct one. This reveals great skills, thus addressing a portrait with practically no prior composition is not a procedure every painter is capable of. However, large directional brushstrokes in the figure's profile and within the disposition of some of its elements can be observed. Infrared images (IR, IRR, IRT) also show the first position of the ruff: the rim of the neck, which was covered with long brushstrokes, allowing us to observe the addition of a light gauze bow tie, seen only in part, because it has been covered by the sash. IRT allows a certain brushstroke analysis technique, which permits one to appreciate the aforementioned construction of the bow tie, but it enhances how the drawing of the coat's decoration also changes its position and inclination. In addition to the repositioning of the left side of the garment's embroidery borders, IR techniques point to the repositioning of the sashes; some corrections or small *pentimenti* over the neck, left arm, shoulder, and finally over the right arm sleeve, which caused, in turn, the shifting of the circular stud patterns, creating therefore a new design [figures 3-4].

XR shows repeated modifications and alterations to the initial composition, allowing us to monitor the compositional evolution of the picture and to establish how the initial idea of the painter was transformed towards achieving a model scheme that satisfied him, in order to make the best of it [figure 5]. Sometimes the *pentimenti* would be significant, with great changes, while others are minor corrections, barely noticeable, in order to balance the compositional dynamics of the portrait or to improve, according to the painter's judgement, weights and rhythms of the chromatic fields which, ultimately, would represent a qualitative increase.

On the right shoulder of the figure, we can observe some white dots (small touches of white lead) which correspond to the buttons that held the sash of the Order of Carlos III as found in other portraits of the King that are preserved. This element, however, disappeared in the early nineteenth century due to a subsequent repainting of the sash.

A striking visible feature of the picture is the absence of the insignia of the Order of the Golden Fleece, that can be found in all other portraits of the King. A barely visible stain under the sashes in IRR suggested the existence of this insignia, and the radiographic image not only

Figure 5-. XR image reveals a complex picture, with light and dark densities, as well what appear to be watermarks in the outline of the figure, caused by the way the canvas is prepared, an unequal primer layer, and the content of white lead (radiopaque material) Due to this radiopacity, the various *pentimenti* and changes hidden by the uppermost visible paint layer can be seen. By radiographic imaging the various paint layers applied on the canvas can be observed. Notice the modifications in head and shoulders, the sashes, the buttons, and embroideries and specially the hands

confirms this hypothesis, it shows that it was originally painted twice. The first is located at a lower level, and was the one initially planned by the painter, together with the sash of the Order of Carlos III and that of St. Januarius of Naples. Subsequently, the artist decided to depict them higher up, along with the Fleece, in a remarkable compositional modification. Therefore, the X-ray shows a second insignia, located higher, which was also hidden by the aforementioned repainting of the sash of Carlos III. It must be noted, however, that the second location of the insignia, in a higher position, is not exactly the one reproduced in subsequent copies. In these replicas, the Fleece is slightly shifted to the left shoulder of the sovereign. We should, therefore suggest, that in the subsequent copies of the original portrait, the artist made some minor adjustments or changes, such as the one described, relocating the insignia due to compositional and aesthetic interests.

The gap left by the artist to paint the head was larger in his first approach, readjusting the trace of the outline by a dark black brushstroke, which implies heavy edges over the lighter fields of the head. Within the creative process of the work we can appreciate how the painter caused a slight movement of the king's head, by using a subtle shift to the left. Whilst on a first sketch his face was probably performed almost entirely frontally, like XR and IRT suggest. Subsequently the painter changed his point of view deciding to slightly swing his head to the left, something which is also visible with IRT and partially suggested by RL. In turn, this repositioning of the head forces him to reformulate the angle of the face features and the hair silhouette, newly modifying his profile by adding a trace on his right side and eliminating another on his left, while he subtly moves his right eye closer to the nose.

Perhaps the parts with greater noticeable changes are those concerning the garments. The biggest issues concern the creation and elaboration of the clothing, the borders of the coat, the sashes, and insignias, and the ornamental elements (modifications that were also visible in IR, IRR, and IRT). In a first draft, the sashes were more distant from the face, conferring the painter space to elaborate an elegant tie, as shown by the XR. The radiograph reveals the existence of very pasted touches of radiopaque material, of high contrast (corresponding to a lead oxide), which leads us to assume that there once was a further elaborated neck. It can also be observed by the remains of the *impasto* that created folds beneath the painted sashes with a different brushstroke direction, partially noticeable with RL.

As we can more clearly appreciate by the X-ray, at first, both the blue sash of Carlos III and the red one of St. Januarius of Naples were located at a lower height, with a further pronounced diagonal angle. Such changes evidence the search for a greater compositional balance. With each alteration of the height of the sashes, in parallel, the position of the Fleece was changed, moving vertically by a few centimeters. With the sashes located in their definitive position, the artist proceeded to decorate the jacket with silver embroidery, yet this was also modified with the general rethinking of most of the garment. Thus, IR, IRR, IRT, and XR images allow us to appreciate a higher initial opening of the jacket [figures 3–5].

Moreover, the right arm of the sovereign must have been of a greater flexure, because the bend of the elbow angle can be seen, creating a dark triangular surface, clearly visible in all the IR images. It is a position similar to the one of infant Don Antonio Pascual, another son of Carlos III, who was portrayed around 1765 by Antón Raphael Mengs in a portrait in the Museo del Prado. In this work, a further opening of the jacket and the right arm of the infant resting on his waist are displayed. This could have been the initial position projected by Goya for the portrait of Carlos IV. This statement can be corroborated by the

hand and sleeve of the right arm which are sensed by observing the XR, as they appear somewhat higher than in the visible composition, which would require, as stated above, a greater elbow flexion. In this initial project, both hands were located at the same level [figure 5]. The right hand appears composed by a semi-closed fist, as if holding an object (perhaps a baton), while the left hand is not well defined, displaced and half-hidden behind the hip for correcting the position. They perfectly match the almost erased stage of the previous composition, noticeable in IR, IRR, and IRT especially. In general, we should point out that this first position or arm composition seems to respond to a less elaborated stage, an idea that was soon abandoned, and it could even be the result of depicting the King while he was sitting down. The less radiopacity is due to a minor content of white lead, expected of a non-finished stage.

Perhaps the whole left area was the least changed. The first outline of the figure was wider and it had to be redone with a second repositioning, which led to a new transformation of the profile, especially the outline of the left side, pushing it to the background of the painting, the edge of which can be seen more clearly. Ultimately, the result is a figure with a typical posture in the paintings of Goya, twisted sideways, with a certain dynamic grace and hidden hands (Puig *et al*. 2016). In general, all these changes (which can be compared with the last stage of the artwork seen in fig. 1) created an improvement in the rhythm of the figure, which slightly pivots over his trunk and head, generating a more natural movement with a communicative turn towards the viewer.

Figure 6-. IRFC. The alteration of the colors can be useful for the primary identification of pigments. Under the red sash (yellow in IRFC by being depicted with vermilion) there is a blue one pushing behind.

Finally, IRFC was also necessary for the initial identification of the pigments (Poldi; Villa, 2006: 127-137); (Cosentino 2014; 2016: 4-5), and even for mapping colors of hidden parts [figure 6]. That is the case of the Prussian blue of the original Carlos III sash, that after the reposition of the sashes remained under the red St. Januarius sash (the yellow one in IRFC, due to its composition of vermilion). Behind the yellowish glowing of vermilion, the Prussian Blue (which also remains blue in IRFC) can be identified. The orange color is due to the presence of the aforementioned lake, noticeable in UVF (Cosentino 2014: 9). All the pigments suggested by MBTI were confirmed by RAMAN. Among them there are vermillion, madder lake, lead white, ochre, and other earthen pigments, as well as Prussian blue and charcoal black., all of them common in the palette of Goya.

Postproduction of images for a proper interpretation

To clearly appreciate all the changes and *pentimenti* already described, it has been necessary to superimpose several images with Adobe® Photoshop® by altering the opacity, not only to get IR and IRR luminosity blends (Cosentino; Stout 2014), but also to create a whole list of blended hybrid images (IR-XR; IRR-VIS; IRR-XR; IRT-IRR; IRT-XR; IRT-IR; VIS-XR), useful to understand the inner divergences [figure 7].

After that, a digital superimposition of various stages of the process of transformation of the portrait was carried out, using a virtual reconstruction based on the evidences of MBTI [figures 8–9]. Furthermore, a careful superimposition the image of the portrait has been done with the replicas or copies by Goya and his workshop, always preserving the original scales. Surprisingly all the figures of the aforementioned portraits coincide exactly with this study case (Puig *et al*. 2016: 88-90). Since all these portraits of Goya's circle show identical measurements and proportions, a tracing technique is very likely to have been used in order to copy the work, although the IR carried out on other portraits has not allowed us to confirm this technique for all the existing examples. Nevertheless, as they all have red primers, it could be done with a white colored tracing paper (invisible with IR techniques), although a common charcoal tracing has been detected on some portraits, like the one of Altadis (Puig *et al*. 2016: 95). Thus, these results prove that there was a single model of the Monarch, of a certain size, that would have been copied repeatedly, although the sizes of

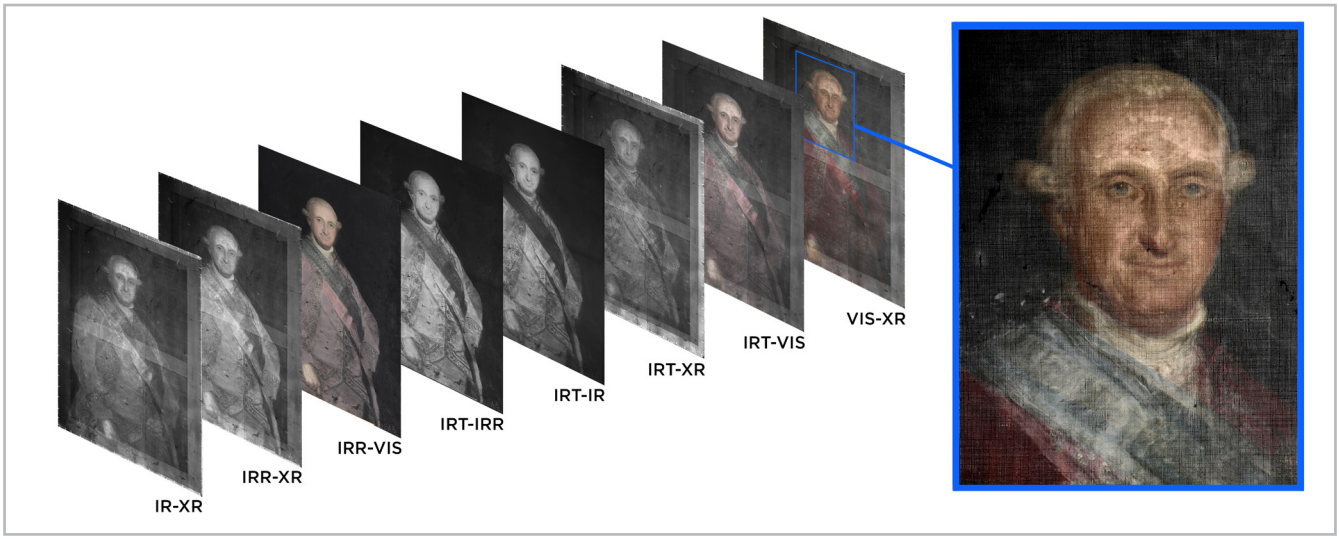

Figure 7-. List of hybrid images developed by blending MBTI images. They allow a better confrontation of results, while they provide useful information that many times cannot be clearly observed with the naked eye.

Figure 8-. Virtual reconstruction of the evolution of the painting, considering the *pentimenti* and underpainting changes noticeable in the MBTI (specially based on XR, IR, IRT, and IRR). (a) First stage and staining. The figure is almost in frontal position, which can be observed in RX and IRT. (b) The first steps and configuration of the model, with a totally different position (maybe the model was seated). (c) Overlapping of all the steps with the final visible image. (d) Final configuration.

the subsequent canvases vary both in height and width. When the Sovereign is represented full-length, only the legs are completed, yet following the dimensions of the body; therefore, the scaling superimposition performed of the three portraits mentioned above results in high accuracy.

Conclusions

With regard to the technical features of the artwork we must review some formal characteristics of the materials and techniques used. Although the work has experienced the addition of various paint layers as a result of successive restorations, the analysis of the original materials allows us to settle an overview of the painter's process, and also offers the possibility to compare it with other works executed by him, whose technical process have also been yet described.

MBTI has lead us to discover the trial-and-error method used by Goya who, reluctant to work in any other way than the one that involved the live model, adjusted every necessary detail until achieving the portrait. Therefore, the painting may be considered the original prototype of the portrait of King Carlos IV, the one created and patented by Goya between February and April 1789, which generated several replicas with the exact same dimensions. Such copies only modified the color of the jackets, the dimensions of the canvas, and the context decoration: curtains, tables and crown. However, all of them displayed identical measurements with respect to the upper and main parts of the Sovereign's portrayed body. Throughout the different images of the MBTI the way in which the portrait was executed has been shown, revealing hidden parts that help to order the steps and stages of the creative process for this particular painting. By carrying out these tests part of the inner history of the

Figure 9-. Virtual reconstruction of the hidden layers of the portrait, superimposed to the VIS layer. This kind of interpretation cannot be carried out without the contribution all the information of MBTI.

painting has been recovered and revealed, discarding the theory that is a copy. Thus, MSI has contributed directly to a final recognition of the painting as the original model and has clarified its attribution to the hand of Francisco de Goya y Lucientes.

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Notas

[1 Centre d'Art d'Època Moderna: http://www.caem.udl.cat/home/

[2] In October 2007 the laboratory Arte-Lab of Madrid conducted a study of the materials from the canvas by analyzing 3 samples. The techniques used were optical fluorescence microscopy, infrared Fourier transform spectroscopy (FTIR), gas chromatography coupled to mass spectrometry (GC-MS) and finally microanalysis performed in the scanning electron microscopy with energy-dispersive X-ray spectrometry (SEM -EDX) Later on, in 2014 a RAMAN spectroscopy analysis was conducted over the whole of the pigments. It was carried out by the RMN service of the University of Lleida. In addition, in 2016 gas chromatographies were carried out to determine the specific binder of the whites as well as the composition of the varnish (Puig *et al.* 2016: 144-145).

[3] Multispectral should be better referred to the imaging systems that use different shots taken at a constant range of 20 or 40 nm, by using special cutting-wavelenght filter, and always by using the same device. (Poldi; Villa 2006:237-238); (Cosentino 2015 a; 2015 b; 2015 c; 2015 f). Hyperspectral is commonly used to refer diffuse reflectance hyperspectral imaging, (or reflectance imaging spectroscopy) which is a sophisticated technique that enables the capture of hundreds of images in contiguous narrow spectral bands (bandwidth < 10 nm), typically in the visible (Vis, 400–750 nm) and the near-infrared (NIR, 750– 2500 nm) regions. (Cucci, et al. 2016, 2070); (Cucci et al. 2018, 45-57); (Vitorino *et al.* 891 901).

[4] https://chsopensource.org/

[5] The grey patches are identified by the following designations (white to black): white; N8; N6.5; N5; N3.5]

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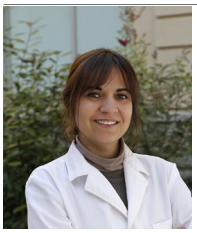

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