Fig. 6 - N. inv. 250: IR/UV False colour

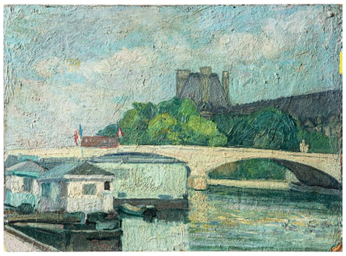


Fig. 7 - N. inv. 250: Photo in the visible optical field through oblique light

(FIGG. 6,7) and 264 (FIGG. 8,9) which apparently do not have any type of signature, as they are erased or covered by paint. In infrared radiation, however, it is still possible to distinguish "Lebourg". Therefore, why falsify a painting whose signature is consistent? From the judicial documents and the memoirs of André Kammermann's lawyer, it is known that some paintings were tampered with in order to conceal the signature in the hope that they would not be seized, a useless effort, as the entire collection was confiscated. Many of the multiple truths hidden within the history of the Kammermann collection are destined to remain unknown since most likely, to an initial nucleus of original works, mostly sketches, models or early studio versions, paintings have gradually been added which, due to greed, were acquired by André Kammermann without the necessary foresight.

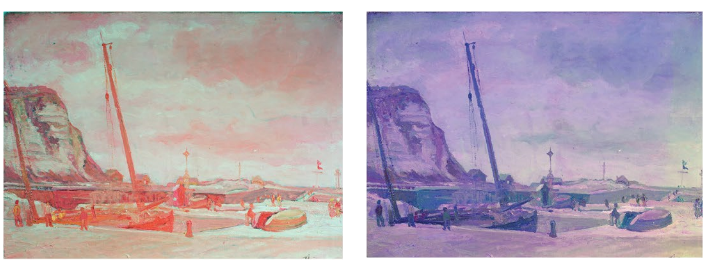


Fig. 8 - N. inv. 264: IR/UV False colour

Fig. 9 - N. inv. 264: IR photo 800 nm.

The diagnostic technique of False Colour and the application of Artificial Intelligence for its interpretation

Cecilia Paolini

The diagnostic technique of False Colour[1] is a non-invasive analysis used to obtain a great deal of information regarding a painted surface, such as the determination of restoration areas with much more precision than a normal infrared reflectography or a photograph of fluorescence induced by ultraviolet radiation[2] and the distinction between pigments of craft or industrial nature. This second result is very important in determining forgeries of old paintings. More generally, this diagnostic technique could also make it possible to highlight the various pigments that make up the painting in order to gather information on the provenance and period of creation.

As explained in the course of this essay however, the interpretation of the results is very complex and above all, subject to arbitrary interpretations that may fatally result in a wrong reading of the colour palette. From another point of view though, this technique has the great advantage of being low-cost, as it exploits the optical capabilities of an ordinary SLR camera, without the need of expensive equipment as with other non-invasive pigment investigation methods such as Raman spectroscopy, X-ray fluorescence spectrophotometry (XFR) and Fibre Optics Reflectance Spectroscopy (FORS).

The basis of this diagnostic technique is the consideration that two pigments producing the same colouring in

Fig. 1 - N. inv. 418: Infrared False Colour and Ultraviolet False Colour from the sky (Prussian Blue)

Fig. 2 - N. inv. 265: Infrared False Colour and Ultraviolet False Colour from the sky (Cobalt Blue)

[1] Alfredo Aldrovandi, Ezio Buzzegoli, Annette T. Keller, Diane Kunzelman, *Investigation of painted surfaces with a reflected UV false colour technique, in proceedings of Art'05 – 8th International Conference on 'Non-Destructive Investigations and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage*, Lecce, Edifimi 2005, pp. 15-19.

[2] Thomas Moon, Michael R. Schilling e Sally Thirkettle, *A note on the use of false-colour infrared photography in conservation*, "Studies in Conservation", vol. 37, 1992, pp. 42-52.

the visible optical field, i.e. Prussian Blue and Cobalt Blue have different colour outcomes when subjected to infrared or ultraviolet radiation (Prussian Blue has a dark blue outcome in the infrared region and turns a deep green when subjected to ultraviolet radiation, conversely, Cobalt Blue appears pink in the infrared region and has a pale green outcome)[3]. This difference is determined by the chemical composition of the various pigments and precisely because they were discovered and used at different times, the chronological terms of their creation can theoretically be deduced from the results of False Colour.

False Colour photography, limited to the infrared region, was developed by Walter Clark in the 1940s for the Eastman Kodak Company, with the aim of detecting forgeries in art[4]. Only two decades later, this technique became accessible to the public thanks to the introduction of infrared film, produced by Kodak and called Ektachrome. During the last decade of the last century, with the advent of digital photography, this method of investigation was systematically applied in the field of the diagnostic analysis of paintings and this research was also extended to the ultraviolet region.

Technically, this investigation is based on superimposing two photographs, one taken in the infrared or ultraviolet region, while the other in visible light. The photograph in infrared or ultraviolet light is translated into grayscale, while that in visible light is divided into the three primary RGB components (Red, Green Blue), resulting in three different images (one for each colour channel). At this point, in False Colour Infrared, the infrared photograph is carried on the red RGB channel, while the decomposition in the red channel derived from the visible photograph is carried on the green channel, similarly the green decomposition on the blue channel and the blue decomposition is disregarded. The same procedure, but in reverse, is applied to obtain the Ultraviolet False Colour: the ultraviolet photograph is transported to the blue channel, the blue decomposition to the green channel, the green decomposition to the red channel and the red decomposition is disregarded. In these new photographs, IRFC and UVFC, the colours obtained do not represent reality, but show the pigment shades in their counterparts in false colours[5] (FIGG. 1,2).

The results obtained in this way, especially if the actual colour fields (in the visible optical field) of the same painting are compared with both the results in infrared and ultraviolet false colour, show different colour triads specific to each colour field. Certainty, the interpretation of IRFC and UVFC photographs (Infrared False Colour and Ultraviolet False Colour respectively) is very complex and inevitably subject to interpretations that depend on the optical sensitivity of the person reading these results[6] (FIG. 3).

VISIBLE	IRFC	UVFC	COLOUR
White	Pale Light Blue	Pale Salmon	Lead White (Biacca) $(PbCO_3)2{\cdot}Pb(OH)_2$
White	Yellow	Pink	White Zinc (zinc oxide) ZnO
Red	Intense Yellow	Blue	Cinnabar (mercury sulfide) HgS
Light Blue	Blue	Green	Prussian Blue (ferrous ferrocyanide) $Fe(III)_4[Fe(II)(CN)_6]_3{\cdot}6H_2O$
Green	Red	Deep Violet	Green Chrome (III)-oxide Cr_2O_3
Brown	Green	Deep Violet	Raw Umber (Hydrated iron oxide) $Fe_2O_3MnO_2nH_2OSiAl_2O_3$

Fig. 3 - N. inv. 035: Chromatic Palette.

The limitations of this analysis are many. First of all, the false colour technique works very well with paintings executed from the beginning of the 19th century onwards, i.e. when massive use of pigments of a synthetic nature (Cadmium, Chromium, Cobalt...) began to be used and even better since the introduction of industrial tube colours (1841). On paintings executed from the 19th century onwards, the colour fields are clearly distinguishable in False Colour as they are sharp and well circumscribed by the neighbouring tonal areas. In older paintings, however, as pigments were sold in powder form and diluted in painters' workshops, they were much more impure, polluted by a strong iron component derived from soil residues. For these reasons, photographs in False Colour are much more imprecise in the definition of the various colour fields, dominated by a green-brown component that is not actually characteristic of the pigments used.

[3] Clotilde Boust, Database: pigments under UV and IR radiations, Hypotheses 2017

[4] Milko den Leeuw, Ingeborg de Jongh, *Technical Art History*, The Hague, Authentication in Art Foundation 2019, p. 14.

[5] Andreas Burmester, F. Bayerer, *Towards improved infrared reflectograms*, in *Studies in Conservation*, vol. 38, 1993, pp. 145-154.

[6] Ingeborg de Jongh, Milko den Leeuw, Jennifer Mass, Daniela Pinna, Lawrence Shindell e Oliver Spapens (a cura di), *Technical Art History. A handbook of scientific techniques for the examination of works of art*, The Hague, Authentication in Art Foundation 2019.

Even in the false colour investigation of paintings after the beginning of the 19th century, certain limits must be taken into account. The first limitation is that, while it is true that each pigment has a different chemical component, and therefore a different optical reaction to infrared and ultraviolet radiation, it is equally true that these differences are very often difficult to distinguish with the human eye. Cobalt Blue, for example shows very similar colour results in IRFC and UVFC to Ultramarine Blue with the only difference being that the latter returns more intense colours (FIG. 4,5). The interpretation of the different shades is therefore

Fig. 4 - N. inv. 539: Infrared False Colour.

Fig. 5 - N. inv. 539: Ultraviolet False Colour.

subjective and depends not only on the critical judgement of the person reading the analysis in False Colour, but also on the physical sensitivity of one's eyes.

False Colour analysis by means of Artificial Intelligence makes it possible to overcome these limits. Several algorithms, in fact, replace the human eye in the analysis of false-colour fields, generating an automatic system that recognises the boundaries of individual colour layers and defines their nature indicating the percentage of certainty of this interpretation. This research system is the result of a project devised by the writer, financed by Fine Art International Switzerland and carried out with the help of engineers Sergio Galeani and Corrado Possieri, who created the system of analysis algorithms, and architect Augusto Marcello Mazzotta, who supervised the verification and control of the results by comparing them with traditional non-invasive investigation techniques for pigment recognition (Raman, XRF, FORS). Not only do the the results obtained have a degree of reliability exceeding 95%, but unlike traditional non-invasive techniques (Raman, XRF and FORS), which give results limited to a single point at a time (FIGG. 6,7), Artificial Intelligence False Colour enables the entire mapping of the colour palette used on the entire painted surface to be detected instantaneously. This technique has also proven to be effective for paintings executed before the 19th century and, as the results are accompanied by the percentage of certainty regarding the recognition of the individual colour field, it is also possible to use traditional non-invasive techniques in a targeted manner only on those areas where the artificial intelligence's reading of the false colour is most uncertain.

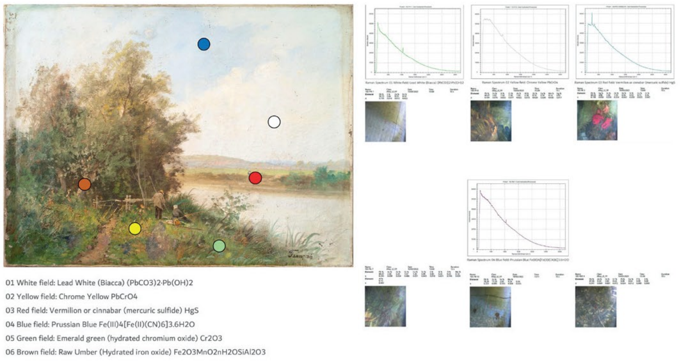
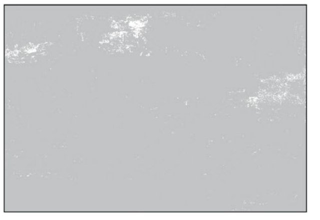


Fig. 6 - N. inv. 183: Raman references.

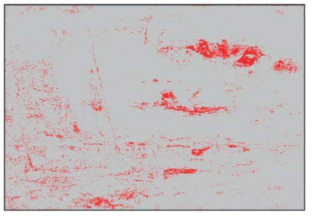
Fig. 7 - N. inv. 264: Artificial Intelligence Fals Colour maps.

A - Lead White

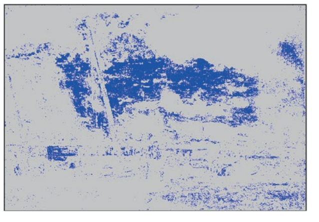
B - Zinc White



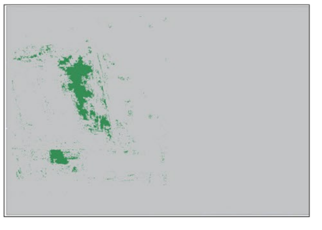
C - Titanium White in form of Anatase



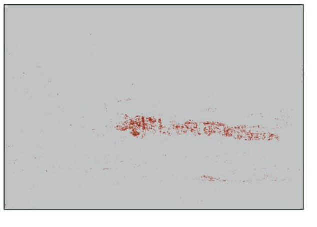
D - Cinnabar (Red)



E-Cobalt Blue



F - Chrome Green



G - Burnt Sienna