Chromatic Image: a New Imaging Method for the Examination of Works of Art

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ABSTRACT

This study introduces a cost-effective and accessible tool, the chromatic image, specifically designed to amplify the visual features of an image during the preliminary stages of the analysis of an art object. The chromatic image enhances the visualization of subtle hues often unnoticeable in traditional colour images. The method involves processing a high-resolution colour image using its chromatic channels (a* and b*) from the CIE Lab colour space. This creates a new image that highlights variations in hues independent of tonal values. This initial research investigates the application of the chromatic image on easel paintings and works on paper. Results demonstrate the technique's effectiveness in revealing details in shadowed areas, enhancing the readability of red chalk drawings, and potentially aiding in damage detection. The method also holds promise for studying brushwork and areas reworked by the artist. This new tool offers a valuable and accessible addition to the toolkits of art historians, scientists, and conservators alike, paving the way for further investigation using more advanced techniques.

KEYWORDS technical imaging, chromatic image, image processing, preliminary examination, forensic imaging

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1. Introduction

Being able to discern an artwork's attributes is very important for every professional in the cultural field. Whether these visual attributes are associated with its aesthetic features (Cubero, 2010), the creative process of its making (Fowler, 2019), or any form of change in structural or aesthetic function (Strlič *et al.*, 2013), the specialist is called to identify and address them.

In heritage science, when such attributes ignite enough curiosity, a research process is pursued to answer queries. Visual inspection remains a fundamental, first approach to identify surface characteristics and potential alterations on the work of art. However, these observations are highly dependent both on one's individual experience and the limits of the human visual system. For this reason, an analytical protocol is usually defined, starting from preliminary techniques – like multiband imaging and XRF analyses – to more selective methods chosen on the basis of the specific research queries.

Among the technical imaging techniques, often included at the preliminary stages of a research inquiry, false-colour composites are a regarded solution for the interpretation of complex data, as they allow to highlight specific features in a scene, visualise information beyond human vision, and enhance the contrast between features. In most cases, false-colour imagery involves the combination of two or three images, of which some carry spectral information outside of the visible range, like NIR or SWIR datasets (Daffara and Fontana, 2011; Legnaioli *et al.*, 2013; Pronti *et al.*, 2019). Yet, the collection of spectral data already falls within the boundaries of an analytical protocol, as it requires specialised training and equipment. Such limit poses accessibility concerns, as readily available methods often serve as the first line of investigation for researchers in smaller institutions and independent professionals (von Saint-George and Lewerentz, 2008; Jaskierny, 2021; Nehring, Girard and Rabin, 2024).

The study presented here aims to introduce the chromatic image, a new visual tool for the examination of works of art at the earliest stage of research without the need for moving the objects from display or storage. The method represents a novel approach to image editing grounded in empirical observation and experimentation, rather than relying on mathematical models. Nonetheless, this new false-colour technique expands the capabilities of visible colour imaging, enabling a swift and informative initial assessment accessible to historians, conservators, and scientists alike.

2. Method

The basic principle behind chromatic imaging involves creating a colour-coded composite image of the chromatic channels (a^* and b^*) of the Lab colour space to enhance subtle differences in hues within a scene. A conventional colour image and an image editing software are required to process a chromatic image. For this study, the author sourced full-resolution TIFF files from the online collection of the Cleveland Museum of Art, which are available for the works of art classified as of public domain. A total of forty-two images of easel paintings, mural paintings, watercolours, prints, and drawings spanning through different ages have been included in the study. Thirty images had colour encoding sRGB 8-bit, while the remaining twelve were encoded in an AdobeRGB 8-bit colour space.

Adobe Photoshop® was used to process the dataset into chromatic images. The choice of this software was driven by its widespread familiarity to photographers, imaging specialists, and conservators who occupy a forefront position in the forensic documentation of artworks in institutions and independent laboratories. While the use of proprietary software limits transparency in the process, its extensive features and capabilities made it a suitable choice for this initial exploration. Future studies could investigate the replicability of the workflow by using other, open-access tools like GIMP, ImageJ, or Python libraries for chromatic image creation. The step-by-step process followed for this study is detailed in Section 2.1 of this article, and a link to a permanent downloadable Adobe Photoshop® droplet is found in Section 5.

When an image is converted from RGB to Lab, the colours in each pixel are described with three coordinates: black opposed to white (L^* or lightness) for the reproduction of the tonal values, green opposed to red (a^*) and blue opposed to yellow (b^*) for the reproduction of the hues. In image editing software, individual channels are visually rendered as a grayscale map of the intensity values for each L^*, a^*, and b^* coordinate. Low values of lightness are represented as dark (pixel values close to zero), while highlights have higher values (pixel values close to 255). In turn, pixels in the channels a^* and b^* can assume positive and negative values, typically between -128 and 127. Negative values for a^* and b^* are represented as darker, while positive values as highlights. Consequently, positive values of a^* (red) and of b^* (yellow) are represented with higher pixel values (> 0); conversely, negative values of a^* (green) and b^* (blue) are rendered with lower pixel values (< 0).

The starting colour image was converted from RGB to Lab, obtaining the three channels L^*, a^*, and b^*. The lightness channel L^* was unaccounted for from here on. Adobe Photoshop® does not allow to work with two-channel images, requiring the handling of the two channels a^* and b^* as greyscale images in themselves, which can then be layered and blended together in a non-destructive way within a three-channel colour space. The 'Screen' blending mode on Adobe Photoshop® was chosen as it consists into a multiplication of the inverse of the blend and base pixel values (Adobe, 2024); in other words, higher pixel values are favoured against lower ones. The effect is similar to projecting multiple photographic slides on top of each other.

A monochrome colour filter was assigned to each chromatic channel. This way, the positive pixel values (corresponding to red for *a** channel and yellow for *b** channel) were rendered with a more saturated hue than the negative pixel ones. The colour coding of each layer was obtained by adding a 'Solid color' adjustment layer (blue for *b** and yellow for *a**) blended to their respective chromatic layers via 'Color burn' blending mode. This blending mode was favoured as it increases the contrast between the base and the blend colour while preserving the luminosity values (Adobe, 2024). The choice of colours to attribute to the *a** and *b** channels was based on the efficacy of the simultaneous contrast derived by the blue-yellow opposition, which results in a higher perception of the details in the scene (Rabin, 2004; Berns, 2016, p. 43).

A final 'Levels' non-destructive adjustment layer was added to adjust the overall tonal range of the chromatic image. Since the intensity values of *a** and *b** can vary considerably from image to image, the tonal range can be optimised by choosing the correction option 'Enhance Per Channel Contrast' (Adobe, 2023). At this stage, the histogram is stretched to cover the entire range of tones, on one side contributing to a stronger contrast between the hues, and leading to the formation of artifacts due to a more or less severe quantisation of the levels.

The resulting project included five layers: a 'Levels' adjustment layer and two 'Solid color' adjustment layers clipped to the layers of the two channels. The sequence of actions ensured a non-destructive approach towards the original values of *a** and *b**. The images were then saved locally as uncompressed TIFF files inclusive of the layers. All the actions were recorded in a macro to run the process automatically at every new image of the dataset and secure repeatability and consistency of the workflow.

It is known that Adobe Photoshop®'s ICC Profile Connection Space (PCS), used in the colour mode conversions, operates with the D50 white reference point (Plaisted, 2011). Other software and coding image libraries may rely on a different standard illuminant (most commonly D65) for the conversion RGB-to-Lab. Given the proprietary nature of Photoshop®'s algorithms, it was not possible to assess what other variables in the RGB-to-Lab conversion may differ from the ones used in other software. No tests were performed to determine the resulting chromatic images in different scenarios than the one presented here.

2.1 *Step-by-step process*

The step-by-step process used for this study is detailed as follows:

1. Convert the colour mode from RGB to Lab
2. From the 'Channels' tab:
   a. Select a* channel
   b. Select all (Ctrl + A)
   c. Copy (Ctrl + C)
   d. Select Lab
3. From the 'Layers' tab:
   a. Paste (Ctrl + V)
4. Rename the new layer as 'a*', untoggle view and select 'Background' layer
5. Repeat point 2 and 3 for the b* channel
6. Delete 'Background' layer
7. Convert the colour mode from Lab to RGB (don't merge layers)
8. Add a 'Solid color' adjustment layer above b*
   a. Assign blue (0, 0, 255)
   b. Assign 'Color burn' blending mode
   c. Create clipping mask (Alt + Ctrl + G)
9. Select a*, toggle view, and assign 'Screen' blending mode
10. Repeat point 8 for a* layer
    a. Assign yellow (255, 255, 0) to the 'Solid color' adjustment layer
11. On top of the existing layers, add a 'Levels' adjustment layer
    a. Set auto correction options to 'Enhance Per Channel Contrast'

3. Results

3.1 *First interpretations and examples*

While colours can be described with three coordinates in the Lab colour mode (lightness and two chromatic axes), the chromatic image exploits only the two chromatic values *a** and *b**. As a result, the final image is a false-colour, spatially resolved map of hues which are present in the starting colour image. It visually describes differences in hues and saturation regardless of their original tonal values. It was observed that the most effective way to interpret chromatic images involved viewing them beside the original image for direct comparison.

As illustrated in Figure 1, the chromatic image is particularly effective in discriminating reds against yellows and greens against blues. A practical example can be found in the watercolour by Honoré Daumier *The Art Lovers* (Figure 2). The chromatic image shows that the small, tinted frame on the right appears to be painted with an orange shade all around then reinforced with a redder wash along the left side. While it does not provide any notion on the pigments' composition, the chromatic image reveals clear insights on the extension of the red passages in contrast to the yellow ones.

All the luminosity values of the starting image are eventually suppressed into a medium grey. Artworks with predominantly neutral tones tend to look flat and lack vibrancy in their chromatic images (Figure 2). This effect is also observed in areas where the artist intentionally left a white background exposed, with the information almost entirely lost in the chromatic image. Additionally, using the method presented here on paintings with thick impasto results in a loss of surface texture in the final rendering (Figure 3). While some may view this as a drawback, it is important to note that the chromatic image emphasizes chromatic information just like other computational imaging methods – like structured light scanning – focus on morphological characteristics alone making these techniques complementary.

The digital suppression of the surface texture may instead play a role in the study of the brushwork and how the paint was applied, as is the case for the highlighted marbling effect of the wet-on-wet passages in Van Gogh's *Two Poplars in the Alpilles near Saint-Rémy*.

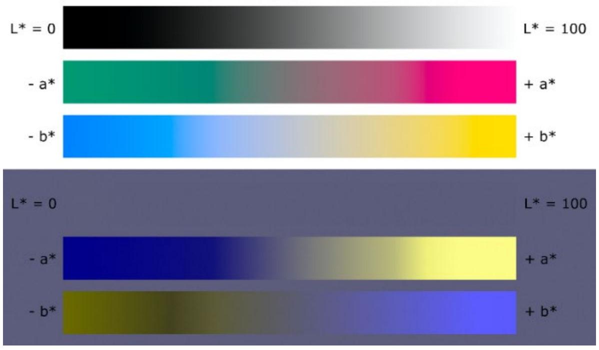

Figure 1. Gradient illustration of the L, a and b channels and their rendering in the chromatic image with adjusted layers value.

Figure 2. Honoré Daumier, Art Lovers, c. 1863. The Cleveland Museum of Art, inv. 1927.208. Left: detail in diffused light; right: same detail in the chromatic image.

Figure 3. Vincent van Gogh, Two Poplars in the Alpilles near Saint-Rémy, 1889. The Cleveland Museum of Art, inv. 1958.32. Left: detail in diffused light; right: same detail in the chromatic image.

The most frequently successful application of the chromatic image was found to be the heightening of shadowed areas, which often emerged with a higher degree of detail than in the starting colour image. The effect seems to stem from the combination of the suppression of the lightness channel – which brings all tonal values to a medium grey – and the simultaneous contrast of the blue-opposed-to-yellow colour scheme. The chromatic images of some particularly dark paintings, like Jan Steen's *Esther, Ahasuerus, and Haman* (Figure 4), reveal the capacity of this technique to enhance the detailing of the architectural features in the background.

A specific case study is the application of the chromatic image for the enhanced reading of red chalk drawings. While any graphite or black chalk underdrawing – as well as white washes and highlights – may get lost in the process, the red chalk marks become remarkably more evident and detailed thanks to the ability of the method to discriminate yellow from red hues. In this specific use case, the chromatic image may acquire an ”inverted colour scheme”, similar to a radiograph, where yellow represents the red chalk marks and the blue is associated with the light orange tint of the aged support (Figure 5). An inversion of the colour scheme may allow for a more convenient reading.

Figure 4. Jan Steen, Esther, Ahasuerus, and Haman, c. 1668. The Cleveland Museum of Art, inv. 1964.153. Top: detail in diffused light; bottom same detail in the chromatic image.

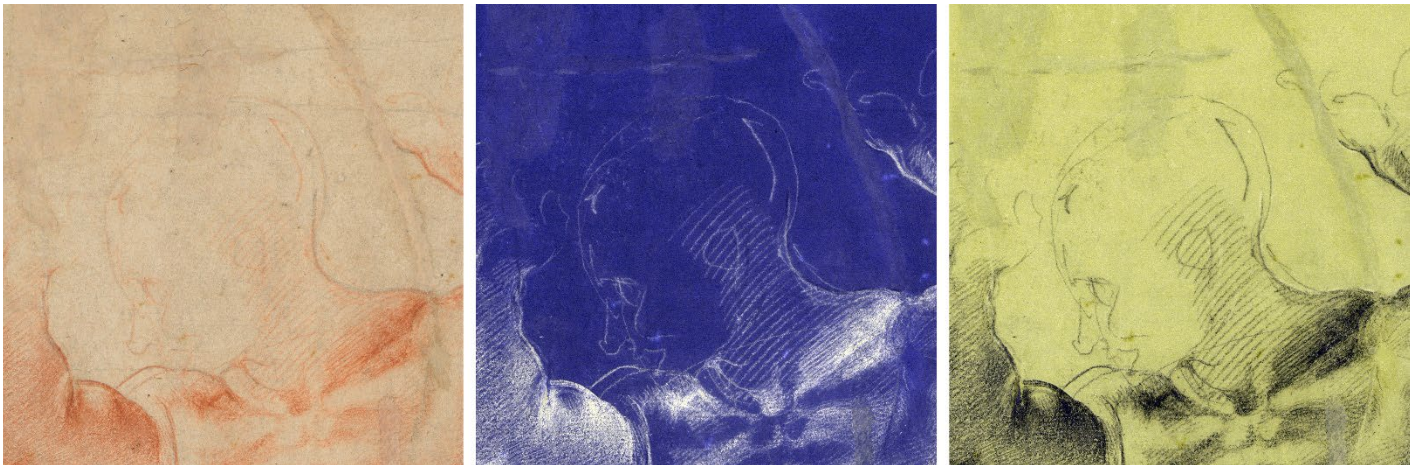

Figure 5. Michelangelo Buonarroti, Study for the Nude Youth over the Prophet Daniel (recto), 1510–11. The Cleveland Museum of Art, inv. 1940.465. Left: detail in diffused light; centre: same detail in the chromatic image; right: chromatic image with colour inversion applied.

In some instances, the chromatic image provided insights on localised damages, especially paint losses and abrasions of the paint film not readily disclosed in diffused light. Its application on works on paper resulted particularly effective in documenting the extension of stains, foxing, and acidic corrosion inherent to the iron-gall ink medium, as seen in the drawing by Fra Bartolomeo in Figure 6. The utility of the chromatic image to monitor deterioration patterns should be investigated with further studies, especially in the context of existing methodologies (Kim *et al.*, 2019). While this new tool can detect various damages affecting the colours of an object's surface, it was not considered reliable in the identification of existing paint retouches – a task better suited for UV-induced luminescence imaging (Webb, 2019).

In a handful of cases, within the relatively small group of artworks processed in this study, the chromatic image highlighted areas of overpaint associated with pentimenti or reworks, as is the case for the foliage in Henri Rousseau's *Fight between a Tiger and a Buffalo* (Figure 7). One should note that chromatic images lack the ability to penetrate objects like infrared or X-ray imaging and that they are limited to highlighting existing details that might be subtle or difficult to see with the naked eye. In this instance, the power of the chromatic image may rely on the suppression of visual noise in complex colour schemes while increasing the contrast between analogous colours.

Figure 6. Fra Bartolomeo, Farmhouse on the Slope of a Hill, c. 1508. The Cleveland Museum of Art, inv. 1957.498. Left: detail in diffused light; right: same detail in the chromatic image.

Figure 7. Henri Rousseau, Fight between a Tiger and a Buffalo, c. 1908. The Cleveland Museum of Art, inv. 1949.186. Left: detail in diffused light; right: same detail in the chromatic image.

3.2 *A note on image quality*

The best outcomes were achieved with an uncompressed TIFF or PNG file as the starting colour image. The lossy compression of the JPEG format resulted particularly evident in the form of its characteristic compression pattern that hampered the overall interpretation. Additionally, the removal of the L^* channel reduces considerably the distinction of details, as it is the channel bearing such information in the Lab colour space (Berns, 2016, pp. 50–68). Starting with an adequate spatial resolution, enough to distinguish small features present on the work of art, represents an advantage.

In order to obtain a faithful separation of hues and ensure replicability of the method, the object should ideally be captured according to established studio photography best practices (Frey *et al.*, 2011; Farnand, 2017) and the image appropriately colour managed using a scene-referred colour chart, where measured values should be preferred against numinal ones (Olejnik-Krugly and Korytkowski, 2020; International Organization for Standardization, 2021; Kirchner *et al.*, 2021). This study did not assess how different colour encodings may affect the final rendering of chromatic images, although a larger gamut found in colour spaces like ProPhotoRGB and eciRGBv2 might result into a more efficient hue separation in images rich in colour fields with subtle gradients.

4. Discussion

As a new visualisation tool with reduced implementation costs, the chromatic image could be readily included in the preliminary stages of any technical or art-historical investigation workflow. During this study, the method offered several new ways of observing works of art. It does not provide any insights on the pigments composition, yet it shows potential in support to the decision making of analytical plans and aid the selection of representative samples. Its applications for supporting conservation endeavours should also be considered, especially as an aid for the location and mapping of areas of damage also on large and monumental surfaces. The use of the chromatic image in the study of drawings and manuscripts is encouraged, especially where partial fading or support discolouration present the necessity to enhance the contrast of the desired marks. This new imaging method may also foster the study of brush marks and paint applications that characterise an artist's working method, as well as bring to light strongly shadowed areas in low-key compositions. Finally, the chromatic image may offer a chance to inspect artworks for potential reworks and overpaints, further characterising the artist's creative process.

A compelling aspect of the applications of the technique presented here is its contained cost, since it does not require specialized equipment aside from the tools of a conventional photographic studio and a robust colour management pipeline, like the one suggested by the American Institute for Conservation (Frey *et al.*, 2011). And while the study presented here relied on the use of a commercial software, a workflow based on freeware, open source software could be investigated in the future, cutting down the costs and increasing further the accessibility of the method.

One of the inherent limitations of chromatic images is the possibility of encountering situations where there simply is no significant feature to be seen – or rather, none of the aforementioned characteristics is highlighted. However, the lack of results should not elude from the notion that more advanced imaging techniques could be more appropriate for the investigation of the object. In fact, chromatic images do not have any penetrative properties, as spectral imaging and radiography do, nor can provide compositional information. Another major limitation could be encountered in case of paintings coated by a heavily oxidised varnish; here, the yellow component may considerably shift the overall signals towards positive values of the a^* channel, masking potentially relevant features coming from other hues. The thresholds of these limits should be investigated in future studies.

Overall, the full potential of the chromatic image is yet to be fully explored, also in the perspective of using other software and image processing libraries that would amplify its accessibility to those institutions and professionals that make large use of open-source tools. For this reason, the author invites researchers in museums and independent laboratories to share their experiences with the author in their use of this new imaging tool.

5. Supplementary materials

A downloadable Adobe Photoshop® droplet for Windows is openly and permanently available on Figshare under licence CC-BY 4.0 at the following address: https://doi.org/10.6084/m9.figshare.26250494.

6. Data availability

The images presented in this study were derived from open source resources available in the online collection of The Cleveland Museum of Art at: https://www.clevelandart.org/art/collection/search?rights=1.

7. Conflict of interest declaration

The author declares no conflicts of interest.

8. Funding source declaration

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10. Short author biography

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