The Scream (ca. 1910) through the Years: from Photographic Documentation to Digital Rejuvenation

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Abstract

Edvard Munch's *The Scream* (ca. 1910) captures the dramatic scene of a human shape overwhelmed by the vibrant sunset over the fjord, painted in oil and tempera on cardboard. Over time, the painting's appearance has inevitably changed, with previous studies highlighting the sensitivity of the yellow and dark red hues to moisture and light exposure. We utilized four color photographs from 1971, 1989, 1993, and 2003 to digitally reconstruct the painting's appearance for those years. The method proposed in this paper addresses the challenges of film degradation by using stable areas of the painting as reference points for advanced color correction. Our results demonstrate the effectiveness of this method in digitally rejuvenating *The Scream* offering a pluralistic glimpse into its potential past appearance.

Keywords: chromogenic film, transmittance spectral imaging, digital restoration, colour correction, polynomial modelling

Introduction

Digital rejuvenation (Berns, 2019) is the attempt to reconstruct the appearance of an artwork as it was in the past, and it is of high interest for a wide range of stakeholders: art historians, conservators, museum curators, educators and the general public. Very often, rejuvenation approaches start from accurate color representations of the artwork based on spectrophotometric measurements of its current status (Kirchner *et al.*, 2018). This is combined with knowledge about the constituent materials and their color change behaviour, which is usually assessed with accelerated aging experiments (Kirchner *et al.*, 2018). In some cases, valuable information about a painting's original composition and appearance can be found in documentary sources (e.g. descriptions of the artist's work in letters, diaries, newspapers) (Stańska, 2024) and/or archival records such as analogue photographs (Tsaftaris *et al.*, 2014; Stenger *et al.*, 2016).

Our research introduces a new method to digitally rejuvenate the painting *The Scream* (ca. 1910) from the Munch Museum in Oslo (Norway), by placing analogue archival records in conjunction with analytical data that informs the process of deterioration in the painting. Four analogue colour photographs of the painting were recorded in 1971, 1989, 1993, and 2003. Our aim is to restore the artwork's colors to how they appeared when the photos were taken. The challenge is that some of these records are themselves subject to color degradation due to the photo-chemical nature of the chromogenic dyes used in films. We overcome this challenge by using scientific data about the materials in the painting and their aging behavior to draw a correspondence between the optical properties of the films and that of the painting, as captured in colour images.

The current article further elaborates on our previously outlined proof-of-concept (Ciortan *et al.*, 2023), by showing the results of adding the stable areas in the painting to obtain accurate colours of the film records. Technically, we use the same mathematical implementations as in one of our previous works (Ciortan and Trumpy, 2024) to obtain a film-to-painting transformation, just that in the current article, we use anchor points from the surfaces of the painting itself, whereas in (Ciortan and Trumpy, 2024) we only use the colour control patches as anchor points.

Method

The earliest known analogue color photograph of *The Scream* (ca. 1910) was captured on large format Kodak film in 1971. This was followed by two large format Agfa films taken in 1989 and 1993, and a 35 mm Fuji film shot in 2003. These photographs collectively document the painting over a span of four decades. Fig. 1 presents the series of these existing reversal films. The degradation of the 1971 film is evident, as it governed by a red cast, provoked by the fading of the cyan dye in the Kodak Ektachrome film.

Fig. 1: The analogue photographs of The Scream (ca. 1910) in 1971 (Kodak Ektachrome), 1989 (Agfa), 1993 (Agfa), and 2003 (Fuji).

After 2003, the digital transition began, meaning that the painting was documented with colour images. At the start of the current study, the most recent colour image of the painting was one acquired in 2017 (Fig. 2). The idea underlying this work is to use analogue films to access the past colours of the painting, while at the same time, the non-fugitive materials and stable zones in the painting are used as reference for correcting the films that withstood dye degradation as well.

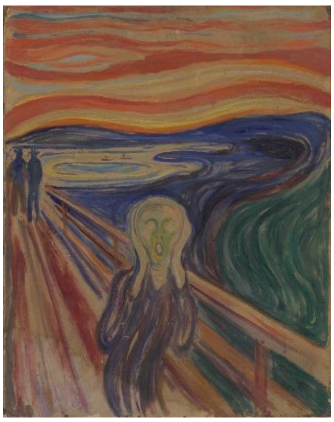

Fig. 2: Digital colour image of the painting captured in 2017, rendered in sRGB space.

In order to accurately capture the optical densities of the films, we designed a transmittance imaging setup, made of a hyperspectral scanner HySpex VNIR-1800 (Norsk Elektro Optikk AS, no date) that collects 186 spectral bands in the 400 nm - 1000 nm range, a translucent white diffuser translation table where the films were placed, and a broadband halogen lamp that backlights the scene. Due to the difference in format between the films, two different lenses were used to achieve comparable resolution. Thus, the large-format films (shot on Ektachrome and Agfa) were scanned with a 30mm lens coupled to the hyperspectral camera, while the 35 mm Fuji was captured with a 10 mm lens.

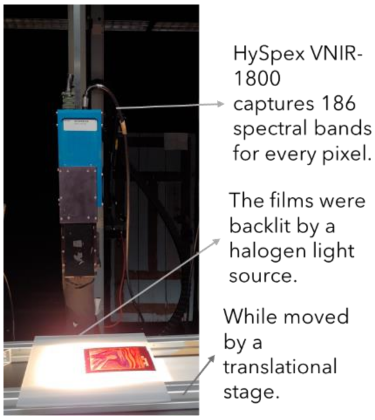

Fig. 3: The transmittance hyperspectral imaging setup designed for scanning the reversal films of The Scream (ca. 1910

Our approach to digital rejuvenation starts with a first pre-processing step, needed only for the heavily aged film from 1971, shot on Kodak Ektachrome. In this step, we adjust the spectral densities of the cyan, magenta, and yellow dyes so that they match the original concentrations, taking the black level in the film as reference (Chatterjee, Trumpy and Ruedel, 2023). This way, we obtain a less unfaded film record of the painting.

Fig. 4: The colour image of the reversal film from 1971, as it looks now (left) and after the pre-processing step (right) involving a spectral adjustment of the cyan, magenta and yellow dyes to make the black in the top part look darker and more neutral, without a red colour cast.

In the second step, we develop a film-to-painting transformation, where we correct the colours of the film record using the painting as reference. From prior investigations, we are aware of which areas in the painting are stable and have not changed during the last decades. Monico et al. (Monico *et al.*, 2020) identified that the yellow brushstrokes in the sky and the main figure's throat have faded because of the chemical reaction between cadmium sulfide pigment and humidity. Additionally, Chan et al. (Chan *et al.*, 2022) employed microfadeometric measurements to assess the lightfastness of various coloured areas in the painting, revealing that the red hues in the sky, painted with vermilion, are particularly sensitive to light exposure. These two sensitive pigments can be mapped thanks to previously processed Macro-XRF scans (Cardinali *et al.*, 2022), where the distribution of mercury (Hg) and the cadmium (Cd) elements indicate where vermilion and cadmium yellow were applied in the painting and if as pure strokes or mixed. In addition, a water damage is known to have occurred in the bottom left corner during the theft of the painting between 2004 and 2006. Thus, all these areas combined charter the substantial changes in the painting, as displayed in Fig. 5. We assume that except from these areas, the rest of the painting is stable and has not changed (see Fig. 6). The stable areas become anchor points to define a transformation from the colours of the slides to the actual colours of the painting. Although each image of the film was geometrically aligned with the image of painting, there are still minor registration artifacts, so that a pixel to-pixel film to paint transformation would be inaccurate. Instead, we summarized the anchor points into 60 meaningful patches, which are the centres of the clusters after k-means segmentation was applied. The number of clusters, 60, was decided following the recommendation of (Hong, Luo and Rhodes, 2001) as being the optimal number for polynomial modelling in digital color management applications.

Fig. 5: The areas in the painting where significant change has occurred. In order from left to right: MA-XRF map of the mercury (Hg) element showing the distribution of the vermilion pigmen; Macro-XRF map of the cadmium (Cd) element, showing the distribution of cadmium yellow pigment; the localization of the water damage in the bottom left corner following the theft of the painting between 2004 and 2006; all the changing points, segmented in the digital colour image of the painting from 2017.

Film 1971 after pre-processing   Painting 2017

Fig. 6: The film-to-painting transformation exemplified for the case of the 1971 film. First, a correspondence is drawn based on the stable areas (what is not masked by white), between the film and the painting in its current state. These areas are further summarized into 60 clusters, to avoid bias for a certain colour group.

Mathematically, we formalize the film-to-painting correction with least-squares regression of polynomial models (first-order, second-order, third order) and neural network fitting, respectively, same as (Ciortan and Trumpy, 2024). We choose the best model according to the mean absolute error given a train-test split of the data of 80%-20%, i.e. 48 points out of the 60 cluster are used for training and 12 points are used for test. The error metric is computed between the values of the film and those of the painting. Finaly, we apply the resulting transformation to each film, which ultimately enables us to peek into the painting's past with improved color accuracy.

Results and discussion

Fig. 7 shows the four films in their current state, as captured with the transmittance, hyperspectral imaging setup, and rendered colorimetrically for the CIE D65 standard illuminant and CIE 1931 2° observer. Fig. 8, Fig. 9, Fig. 10, and Fig. 11 show the colours of the films after correction with the four methods: baseline (first-order polynomial and look-up table), second-order polynomial, third-order polynomial and neural network, respectively. Numerically, the neural network method yields the lowest error when comparing the stable areas (Fig. 6) between each colour corrected film and the version of the painting in 2017 (Fig. 2). It is difficult to quantify the performance of the methods in the non-stable/fugitive areas, corresponding to vermilion or cadmium colours, as we do not know with precision the extent of change with respect to the current colours of the painting.

Fig. 7: Colour images of the reversal films, as they are in their current state: 1971 (Kodak Ektachrome), 1989 (Agfa), 1993 (Agfa), 2003 (Fuji).

Fig. 8: The colour corrected films with the baseline method: 1971 (Kodak Ektachrome), 1989 (Agfa), 1993 (Agfa), 2003 (Fuji).

Fig. 9: The colour corrected films with the neural network method: 1971 (Kodak Ektachrome), 1989 (Agfa), 1993 (Agfa), 2003 (Fuji).

Fig. 10: The colour corrected films with the second order polynomial: 1971 (Kodak Ektachrome), 1989 (Agfa), 1993 (Agfa), 2003 (Fuji).

Fig. 11: The colour corrected films with the third order polynomial: 1971 (Kodak Ektachrome), 1989 (Agfa), 1993 (Agfa), 2003 (Fuji).

Generally, one of the challenges of digital restoration approaches is given by the lack of ground truth. A way to cope with this is to check the consistency of well-known colour change behaviours of some pigments. For instance, vermilion is known to darken with the passing of time, and this is perceivable in our results in the sky region, where the vermilion brushstrokes become darker in the 2003 colour-corrected film with respect to the 1971, as displayed in Fig. 12.

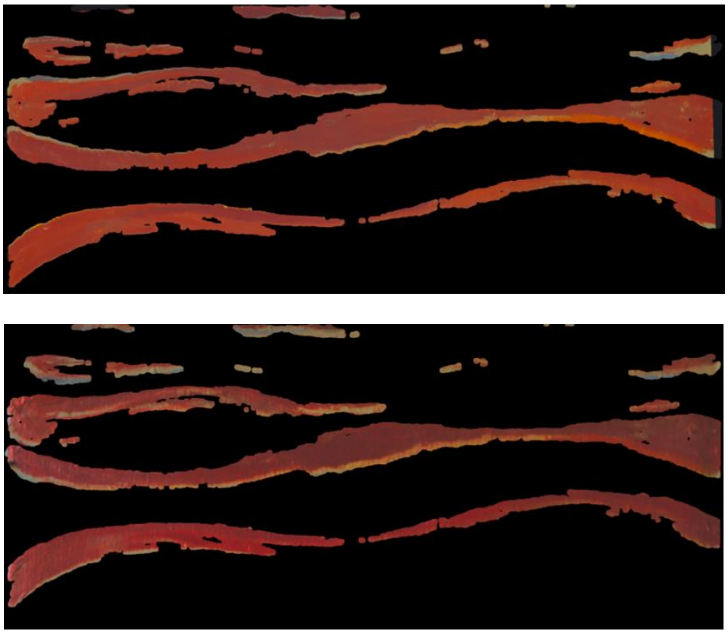

Fig. 12: Details corresponding to the vermilion brushstrokes in the sky of The Scream, taken from the colour corrected film records (with the neural network approach) from 1971 (top) and 2003 (bottom). The darkening effect typical to vermilion is obvious, which supports the fact that the corrected film records can be used as evidence of the past appearance of the paintings.

Another way to cope with lack of ground-truth of the digital restorations is to consult documentary sources. In this regards, there is a description of the scene depicted in *The Scream* motif by the artist Edvard Munch himself, that mentions a dramatic sunset, where the red looked like “blood” and the yellow like “tongues of fires”, as follows: “I was walking along the road with two friends – the sun was setting – suddenly the sky turned blood red – I paused, feeling exhausted, and leaned on the fence – there was blood and tongues of fire above the blue-black fjord and the city – my friends walked on, and I stood there trembling with anxiety – and I sensed an infinite scream passing through nature.” *(Stańska, 2024)*. According to artist’s description, we would expect a very intense, vivid and saturated red in the sky, as well as a high contrast between the red and the yellow tones. The method that achieves best this dramatic sunset effect is the third-order polynomial, as can be seen in Fig. 11. Nonetheless, the restorations for the 1993 and 2003 with the same method yield somehow unnatural colours in the face area and adds a bit of black in the sky area that is unlikely to have been there. Furthermore, the method that restores the dullest and desaturated colours for the sky is the baseline, followed by the second-order polynomial, while the neural network attains a good balance between realism and level of vividness of the sunset effect.

It is important to stress that every digital restoration is speculative in nature albeit our effort to root the process in a comprehensive set of scientific data from multiple sources—elemental mapping, color and spectral imaging, artificial aging experiments, and documentary sources. One of the advantages of our work is that it offers multiple possibilities to showcase the painting's past appearance depending on a certain choice of method and parameters, without issuing a final judgement on which result, if any, is the undeniable truth. The choice of the most probable restoration is a complex process and the verdict needs to be discussed and debated by a panel of experts, which we plan to fulfil in the future.

Conclusions

This research presents a comprehensive approach to digitally rejuvenating *The Scream* (ca. 1910) by leveraging analogue archival photographs and scientific data on the painting's material degradation. By addressing the challenges of chromogenic dye degradation in film photographs, we developed a film-to-painting transformation method that uses stable areas of the painting as reference points. Our comparative analysis of polynomial models and neural network fitting revealed that the neural network method yielded the lowest error in color correction. The results highlight the potential of our method to provide pluralistic representations of the painting's historical appearance, contributing to the preservation and understanding of cultural heritage. Future work will focus on further objective and subjective evaluation of the various restoration results by experts in the field of art history, conservation and conservation science.

Acknowledgement

This work was partially funded by the Horizon EU PERCEIVE project (2023-2026), under grant agreement nr. 101061157.

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