Spectral Estimation of Artist Oil Paints using Multi-Filter Trichromatic Imaging

Francisco H. Imai and Roy S. Berns

Munsell Color Science Laboratory
Chester F. Carlson Center for Imaging Science
Rochester Institute of Technology
54 Lomb Memorial Drive, Rochester, NY 14623-5604, USA.
Phone: 716-475-7842 Fax: 716-475-5988 email: imai@cis.rit.edu

Abstract

In many museums, once an image is captured, deficiencies in the imaging capture system are usually handled through visual adjustments of tone and color balance using tools such as Adobe Photoshop™. Although these adjustments can produce pleasant results, they are not acceptable in terms of color accuracy for applications such as digitally archiving artwork.

Multi-spectral capture can give a more accurate representation of the image. In order to improve color accuracy, the National Gallery in London, UK has pioneered the development of a multi-spectral imaging system resulting in a colorimetric image archive for their collection. However, colorimetric matching decisions are prone to problems associated with metamerism: intransigence to change in illumination, lack of forgiveness for differences between individuals and the standard observer, and high sensitivity to printer noise and calibration errors. Spectral-based reproduction is far more robust with respect to these limitations.

At Munsell Color Science Laboratory, we have been drawing upon this body of successful work and going several steps further to produce an end-to-end scene to hardcopy spectral reproduction system. The spectral information provides printed color reproductions that are close spectral matches to the original objects producing high-quality color matching under different illuminations and observers. Particularly, the input part of system is very critical for the quality of the image because color inaccuracies due to the image acquisition and spectral estimation propagate and they are amplified throughout the imaging and printing processes. The first and most direct method to capture spectral data is to increase the sampling increment above the traditional three channels using highly selective, spectrally narrow filtering. The acquisition system becomes a spatial spectrophotometer with appropriate calibration providing a method that is robust for any arbitrary spectral shape. However, we also need to consider other multi-spectral acquisition approaches that would be sufficiently easy, fast, simple to be implemented in museum archival departments, and that provide reasonably accurate spectral reflectance estimation. Considering the smoothness of the spectral curves of the most commonly used pigments, it is possible to reduce the number of channels by means of principal component analysis. Based on these facts we proposed a wide-band image acquisition combined with either a number of colored filters or a number of differently colored light sources. The captured images are converted to a spectral reflectance image using colorant information known *a priori*. In this case, if the colorants for a particular painting are available it is possible to make targets with the colorants to perform *a priori* spectral analysis. However, generally such an information is not readily available without performing either historical or chemical analyses of the paintings.

In this paper we present a method of spectral reflectance estimation for paintings using a transformation from digital signals to reflectance based on *a priori* analysis of a general, universal oil painting target.

In our experiments we used two oil paint targets. One of the oil painting targets, that we call Ross target (painted by Ross Merrill, Head of Conservation at the National Gallery of Art, Washington, DC), was created using 68 pigments dispersed in linseed oil representing blues, greens, yellows, reds, earth colors, browns and radiant colors commonly used by artists. Another oil painting target, called van Gogh target, was created by Roy Berns, consisting of 106 patches made from cobalt blue, prussian blue, naples yellow, yellow ochre, cadmium red medium, ivory black, and titanium white, representative of the colors present in one van Gogh self-portrait painted in 1889, part of the Whitney collection at the National Gallery of Art, Washington. The paints chosen for the van Gogh target were based on spectral measurements performed on the self-portrait painting.

Both Ross and van Gogh targets were imaged using the same illuminants, set of absorption filters, camera system and imaging geometry. The Ross target was used as a universal target. The eigenvectors of the Ross targets was computed from its measured spectral reflectances. A transformation was derived to convert digital signals to spectral reflectances using the computed eigenvectors. The transformation derived for the Ross target was used to derive the spectral reflectances of the van Gogh target from the digital counts of the van Gogh target. Table I shows the colorimetric and spectral performance between the measured and predicted spectral reflectances of the van Gogh target using the transformation derived for the Ross target.

Table I. Colorimetric and spectral accuracy of van Gogh oil painting target spectral estimation using six signals (R,G,B without filter and with light-blue absorption filter) using transformation derived for the Ross target.

Measure	**ΔE^*_{94}(D50, 1931)**	**reflectance factor rms error**	**Metameric Index (ΔE^*_{94},D50, 1931)**
Average	**1.7**	**0.022**	**0.3**
Std Dev	1.0	0.016	0.2
Max	4.5	0.091	1.1
Min	0.3	0.004	0.03

The results we obtained show encouraging evidences that make possible to design a universal target to derive the eigenvectors that are necessary for the spectral estimation. The use of a universal target will be fundamental for the cases in which we do not know the spectral characteristic of the pigments of a particular painting.

Keywords:
Image input, digital image capture, artwork reproduction, multi-spectral acquisition, spectral estimation

Biographical sketch of the primary author:
Dr. Francisco Hideki has a Ph.D. in Imaging Science from Chiba University in Japan. Since September 1997 he has been working at Munsell Color Science Laboratory at Rochester Institute of Technology. His research has been focused on high-spatial resolution multi-spectral image capture and spectral reconstruction. . He was named as the recipient of the 1998 Itek Award for the best student paper in 1997 by The Society for Imaging Science and Technology.