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A Multispectral Dataset of Oil and Watercolor Paints

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Abstract

We publish two carefully prepared and spectrally measured datasets of paint swatches. The main advantage of these datasets is that a diverse set of paint mixtures are manually prepared the way an artist may create them. The ratio of paints in each mixture is also published. The first set has 286 swatches made from 8 tubes of Old Holland oil paints in different combinations. The second set has 397 swatches made from 9 tubes of Schmincke watercolor paints. We provide exact details about the preparation of our swatches. We analyze the colorimetric and spectral properties of the two datasets in order to show the spread of the colorimetric gamut and the intrinsic, spectral dimensionality of the datasets. The dataset will be available on http://cam.mpi-inf.mpg.de/ and http://www.azadehasadi.com/ .

Introduction

In the majority of available paint datasets [1], a large number of paint tubes are used to get different hues, with black or Titanium white paints added to create different values. Paints are only “computationally” mixed together, or not at all. This method has a main disadvantage: painting artists rarely use it. As one major motivation of publishing this kind of dataset is fine art reproduction for cultural heritage preservation, paint swatches need to be created following the method of artists.

Prominent painting artists use only a limited number of paints. Their so called “limited palette” is highly praised by art critics for better painting unity, balance, color harmony, cool-warm color contrasts, less over-mixing mud, more economical, etc. Black is either avoided or used cautiously in mixtures as it is believed to “kill” the hue. To create dark values, artists create their own shade of black by mixing “complementary” colors, e.g. red and green. Titanium White gives chalky opaque characteristics to a mixture; therefore, oil paint artists sometimes lighten their mixtures using the more transparent Zinc White, or a mixture of Zinc and Titanium White. Watercolor artists avoid white and simply use water to dilute and lighten up the paints.

Experimental Setup

Our database is prepared in the fashion of artists. We use only 8-9 tubes of paint for the oil/watercolor paint datasets, and mixed these together to cover the color gamut. For each mixture, all the ingredients were weighed carefully to achieve the desired proportions. In case of oil paints, a mixture of Zinc and Titanium white is used to lighten up the created hues in different steps. Black paint was avoided and dark values were created through mixing complementary colors.

Swatch Preparation

Oil Swatch

For oil paint swatch database, we used 8 tubes of paint based on Claude Monet’s palette (Table 1), and mixed these together to cover the color gamut. Mixtures with 2, 3, 4, and even a few 5-paint ingredients were made. For each mixture, all the ingredients were weighed carefully to achieve the desired proportions. A mixture of Zinc and Titanium White was used to lighten up the created hues in different steps. Black paint was avoided and dark values were created through mixing complementary colors.

Table 1. List of oil and watercolor paints used for the preparation of datasets.

Oil (Old Holland)	**Watercolor** (Schmincke)
Scheveningen Yellow Lemon	Lemon Yellow
Cadmium Yellow medium	Cadmium Yellow light
Scarlet Lake extra	Yellow Ochre
Alizarin Crimson Lake extra	Cadmium Red light
Cobalt Blue	Prussian Blue
French Ultramarine light extra	Ultramarine Finest
Viridian Green deep	Phthalo Green
Mixed White	Permanent Carmine
--	Ivory Black

The oil paint swatch step-by-step preparation follows: For each mixture, comprising paint ingredients are weighed one by one on a disposable non-absorbent laboratory sample paper. The following scale was used for all weight measurements: Smart Weigh Pro Pocket Scale, readability: 0.01 gram. The ingredients are then mixed patiently and thoroughly using a metal mixing knife. The base for the swatches is a sheet of Arches oil paper (100% cotton, 300 gr) that has been divided using masking tape into 20x20 mm^2 spaces. The mixture is spread on the designated square space by the edge of a flat metal painting knife so that the swatch has a smooth surface finish. Negligible amount of paint will be left on the masking tape. When all square spaces on a sheet of paper are filled, the paper is stored in a closed plastic container, and left to dry for a few weeks, away from possible dust or contamination. Once dried, the masking tapes are removed to reveal a tidy sheet of paper containing 35 swatches bordered by the white of the paper.

Watercolor Swatch

For watercolor paint swatch database, we use 9 tubes of watercolor paints and their mixtures (Table 1). The main challenge for creating watercolor patches arises from its main ingredient: Water. This is why the previous work has avoided the use of water in their watercolor dataset [2]. Water is used to dilute and lighten up the samples, and is added in relatively very large quantity to achieve the light values. It wets and distorts the paper, runs freely around the swatch space carrying and depositing the pigments here and there, so that the most non-uniform swatch is made. Water is less viscous than gum arabic, the liquid that carries the pigments in a paint tube, therefore, the more water is added to a paint, the bigger the challenge. One might think of avoiding this challenge by using watercolor white paint instead of water to lighten up the paints, however, this will make the colors greyish, chalky and opaque. Transparency of colors is watercolor paintings' most important feature.

To resolve this issue, we pour the sample on a flat silicon brush and sweep it in a continuous forward motion on the paper, so that small amounts of sample liquid flows from the brush and lands on paper and is completely absorbed at that location as the brush moves forward to deposit the rest of the sample liquid. The result is a uniform rectangular patch, with the width of the silicon brush, but varying in length depending on how viscous different sample liquids are (note that sample liquid amount is constant). Although the viscosity of each paint tube is different, the sample viscosity depends mainly on the proportions of water as the dominating ingredient in each sample. Therefore, the size of the rectangle patch for all samples with similar paint to water proportions is approximately constant. This means that the concentration of paint on a given location on the rectangle patch is the same for different samples with similar paint to water proportions. We cut out a small square area within each rectangle patch to represent the swatch for that sample.

The watercolor paint swatch step-by-step preparation follows: for each mixture, water and the comprising paint ingredients are weighed one by one and added inside a glass jar. The following scale was used for all weight measurements: Jennings Scale js-100xv, Readability: 0.01 gram. The ingredients are mixed thoroughly using a soft mixing brush, then 0.05 milliliter of this mixture is taken using disposable medical grade syringe (Injekt-F 1 ml syringe, Readability: 0.001 milliliter) and spread using a size 25 flat silicon brush on paper (Hahnemühle Fine Art Archival Inkjet Paper, 280 gr), as explained earlier. Next, we cut hollow square frames with 18 mm inside and 24 mm outside dimension using a laser cutter from the same Fin Art paper. We paste the frame on an appropriate location on each patch to designate the swatch area. Then we cut around the outside of these frames to extract the square swatches bordered by the same paper as the substrate.

Multispectral Measurement

We measure both datasets using a sphere spectrophotometer, namely the X-Rite Color i7 instrument. This instrument provides a diffuse incident illumination through an integrating sphere. The diffuse incident light falls on the measured sample at all possible angles and the sensor captures the reflected light at 8° from the normal incidence. The response is in the form of reflectance factor with 10 nm sampling intervals from 400 nm to 700 nm. The device gives the possibility to include or exclude the specular component reflected off the sample. We publish the specular-excluded measurements.

Data Analysis

Spectral Analysis

Figure 1 shows the measured spectra of both oil and watercolor underlying paints in their purest form. In order to explore the "true" spectral dimensionality of the paint datasets, we perform a compression and decompression of these datasets using the well-known Principal Component Analysis (PCA) [3]. We use different number of bases for the compression/decompression. In order to find the number of dimensions where we can losslessly present the spectral dataset we show the reconstruction (decompression) error in terms of perceptual color differences. Figure 2 shows that, for both datasets, highly faithful reconstruction is within reach with 7 spectral bases hinting at the spectral dimensionality of this dataset. The plots show the compression loss in terms of CIEDE2000 where we reconstruct the original spectra using different number of principal components. The oil dataset is slightly more challenging to compress than the watercolor dataset. But both of them can be reconstructed with a CIEDE2000 error less than 0.5 using 7 dimensions.

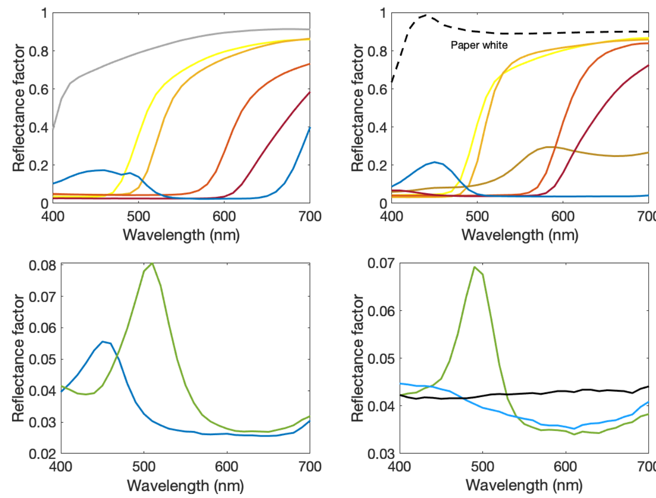

Figure 1. The measured spectra of underlying paints (Table 1). The left column shows the oil and the right column the watercolor paints. For a better visualization, the top row shows the lighter and the bottom row shows the darker paints.

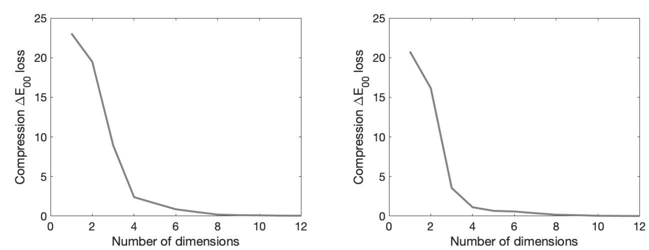

Figure 2. The reconstruction error of the oil paint dataset (left) and watercolor dataset (right) after being compressed with a different number of PCA bases. The reconstruction error is reported according to the CIEDE2000 color difference formula under the D65 light source.

Colorimetric Analysis

Figure 1 shows the CIE a* vs b* chromaticity plot of the two datasets. The graph shows the colorimetric spread of these dataset in a 2D plot by projecting all CIE L* slices on a single plane. We can see that the data covers the chromaticity space well, given there are only a few hundred patches. For both datasets, the area for violet colors are not well covered. The reason is that one cannot get good violet colors by mixing and a separate paint tube that contains only violet pigment is required. The same is true for the cyan region of the color space. Again, one cannot create good cyan colors by mixing and a separate paint tube, usually called the

Cerulean Blue is needed. In future, we may add this kind of pigments to the datasets.

Conclusion

One important application of these datasets is the reflectance reconstruction of paintings where we only have camera data. We can rely on these datasets to estimate the spectra of a painting with high spatial resolution. This will enable applications in conservation and reproduction of fine art heritage. Since we publish the ratios of paint in the mixture in each patch of the dataset, we can use these data to test or develop paint mixing models like the well-known Kubelka Munk model. Also, this work can be a painter's guide. It would be interesting for painters to see the range of colors that could be made by mixing. In future, it is interesting to prepare other kinds of swatches using non-traditional paints and inks, such as metallic inks [4,5] or pearlescent inks [6].

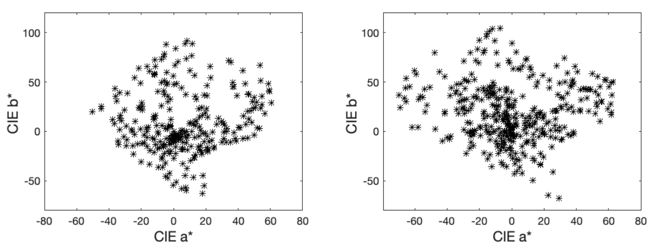

Figure 3. The CIE a vs CIE b* chromaticity plot of the oil (left) and watercolor (right) dataset.*

Acknowledgements

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Author Biography

Azadeh Asadi Shahmirzadi received her Bachelor of Science in Tehran, Iran at Amirkabir University of Technology in Chemical Engineering. She received her first Master of Science degree from University of Alberta, Canada. Her thesis was on pipeline transport of two-phase flow of water and clay particles. She received her second Master of Science degree in Actuarial Sciences from HEC Lausanne in Switzerland. She currently works as an artist-in-residence on art-related technological projects.