Multiangle visual validation of a physically based rendering of goniochromatic colors

Conference Paper · August 2021

6 authors, including:

Khalil Huraibat
Arab American University
22 PUBLICATIONS 36 CITATIONS

E. J. J. Kirchner
AkzoNobel Performance Coatings
111 PUBLICATIONS 790 CITATIONS

Ivo van der Lans
AkzoNobel
30 PUBLICATIONS 159 CITATIONS

Joaquin Campos
Spanish National Research Council
157 PUBLICATIONS 1,039 CITATIONS

Multiangle visual validation of a physically based rendering of goniochromatic colors

Khalil Huraibat [1,*], Esther Perales [1], Eric Kirchner [2], Ivo Van der Lans [2], Alejandro Ferrero [3] and Joaquín Campos [3]

[1] Department of Optics, Universidad de Alicante, Alicante, Spain; khalil.huraibat@ua.es, esther.perales@ua.es
[2] AkzoNobel Color Technology Group, Sassenheim, the Netherlands; eric.kirchner@akzonobel.com, Ivo.VanderLans@akzonobel.com
[3] Instituto de Óptica, Consejo Superior de Investigaciones Científicas, Madrid, Spain; alejandro.ferrero@csic.es, joaquin.campos@csic.es
* Corresponding author: khalil.huraibat@ua.es

Abstract
In this work, we evaluate the capability of a physically based rendering framework to reproduce the color flop phenomena of effect coatings through psychophysical tests. For this task, a digitally simulated lighting environment (the Byko-spectra effect light booth) is built to set up the visual tests, in which physical objects inside the physical light booth are visually compared to the rendered images of virtual objects inside the virtual light booth. Two separate visual tests were conducted by judging the color variation on flat and curved metallic painted panels. Fifteen metallic samples were selected in order to cover different hues and color flop values. Both tests show good intra- and interobserver reproducibility. We found that observers are more tolerant when judging curved samples; the acceptability of visualizing the sample colors over various angles was highest at 97% when using curved panels, versus 80% when flat panels were evaluated.

Keywords: *Goniochromatism, physically based rendering, visual assessments*

INTRODUCTION

Rendering of gonio-apparent coatings is a very active hot topic since this type of coatings changes considerably its visual attributes such as color and texture with the illumination/viewing geometry. It is complex to characterize the appearance of these coatings due to the presence of special effect pigments, which can be metallic, interference or pearlescent pigments (Maile et al. 2005; Pfaff 2009; Klein and Meyrath 2010).

We recently developed a fully spectral rendering pipeline that we use for creating physics based-rendered images (Kirchner et al. 2019; Huraibat et al. 2021). The rendering is based on physical measurements, and it makes use of the spectral, spatial and angular distribution of the reflectance to improve the color reproduction accuracy. In addition, it allows real-time rendering and only requires modest hardware and display (iPad display computer). This framework is dedicated to rendering complex materials such as gonio-apparent coatings, gloss, sparkle, but it can also be adapted for rendering other textured materials. The rendering is based on the spectral reflectance and texture measurements of the BYK-mac i Multiangle Spectrophotometer. It takes as input the spectral, angular and spatial data, and also the physical models of the reflectance of these kinds of coatings (Kirchner et al. 2012; Kirchner et al. 2015; Ferrero et al. 2013).

In this work, we focus on evaluating the capability of the presented rendering framework to reproduce the color flop phenomena of effect coatings. Through psychophysical tests we evaluated the changes in color at different viewing geometries. For this task, a digitally simulated and well-defined lighting virtual environment, commonly used in industry and specifically for evaluating the appearance of gonio-apparent coatings (the Byko-spectra effect multi-directional light booth, Figure 1) is virtually built to set up visual tests, in which physical objects inside the physical light booth are visually compared to the rendered images of virtual objects inside the virtual light booth. Two separate visual tests were conducted by judging the color variation on flat and curved metallic painted panels at different viewing geometries.

Figure 1: The Byko-spectra effect light booth (BYK-Gardner). The left image shows the inner structure and the rotation platform of the light booth.

In the current phase of the investigation, we focus on color aspects only and observers were asked to ignore other aspects of appearance. Fifteen metallic samples were selected in order to cover different hues and color flop values. Observers were asked to judge the perceived difference between the simulated and the physical panels, by using an evaluation score ranging from “0: No/ hardly any difference” to “5: large difference, very bad match”.

In future work, we will extend the analysis to include accurate rendering of graininess and sparkle.

METHODS

To achieve an accurate rendering of colors, it is important to have a well-characterized lighting environment. Therefore, we firstly built a well characterized virtual model of the Byko-spectra effect light booth. Six different models of the virtual light booth were built, one for each of the illumination-viewing geometries (45as-15, 45as15, 45as25, 45as45, 45as75 and 45as110) supported by the Byko light booth and the BYK-mac i instrument.

Two separate visual tests were conducted by judging the color variation on flat and curved metallic painted panels at different viewing geometries. Figure 2 shows a screenshot of the flat and curved panels simulation for the same physical sample as viewed on the iPad screen. The final rendered images on the iPad screen mimics the viewing slit on the physical light booth. The tablet is placed next to the viewing slit to allow a simultaneous visual assessment of both the virtual and the physical object under study. The evaluations were carried out in a dark room with two minutes for dark adaptation before starting each test. All the selected observers pass the Ishihara test and have normal color vision.

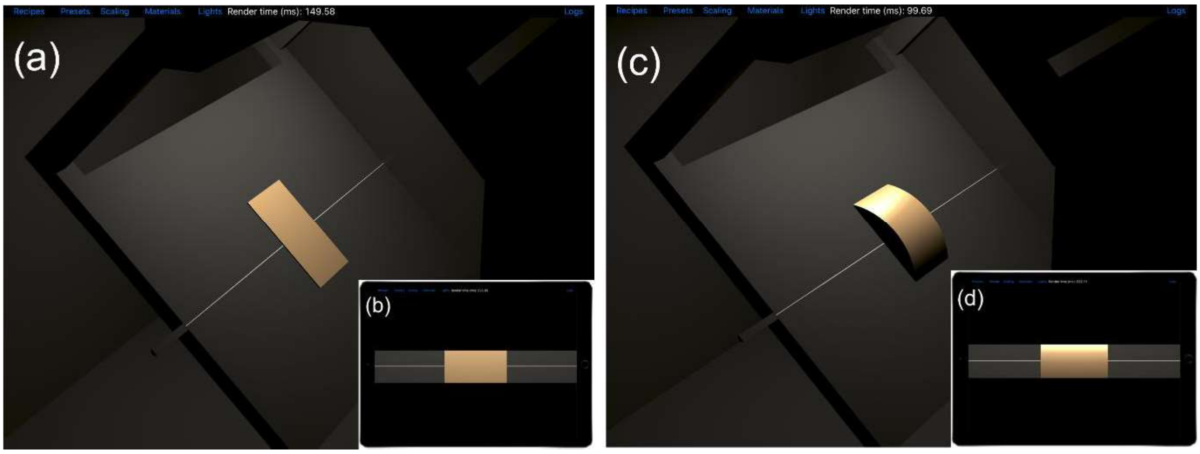

Figure 2: Screenshots of the real-time rendering on the iPad of color-only simulation of a metallic coating panel inside the virtual light booth. (a) shows a flat panel simulation at geometry 45as45. (c) shows a simulated curved panel. The observer view on the tablet is represented in the sub-images (b) and (d).

In the current phase of the investigation, we focus on color aspects only and observers were asked to ignore other aspects of appearance. Fifteen metallic samples were selected in order to cover different hues and color flop values. Observers were asked to judge the perceived difference between the simulated and the physical panels, by using an evaluation score ranging from “0: No/ hardly any difference” to “5: large difference, very bad match” as shown on Table 1.

Score	**Description**
0	No / Hardly any difference
1	Small, negligible difference
2	Difference visible but still acceptable
3	Difference visible, doubtful match
4	Difference clearly visible, not correct match
5	Large difference, very bad match

Table 1: Descriptions of scores for the Scoring method.

The first test addressed color matching of flat panels, where a total of 60 different judgements were performed at three different geometries (as25, as45, as110). An additional judgement of the total color travel is also preformed after judging the previously mentioned three geometries. For the total color flop evaluation, observers continuously swapped between the renderings of each panel at different angles, thus simulating sweeping in the Byko-spectra effect light booth. The evaluations were performed by 5 different observers and included repetitions.

The second test was carried out by evaluating 3D objects. Observers evaluated the perceived color difference for curved and color-only rendered images by comparing them to the curved physical panels. A curved magnetic platform was used, and the samples were placed on top of it to mimic 3D objects. 8 different observers judged the color matching at four different geometries (as-15, as25, as45 and as110) for each of the 15 samples, i.e., 60 visual judgments in total.

RESULTS

The rendering tool is well able to reproduce the color flop of effect coatings as seen in Figure 3. The color change is easily perceived, and the panels are getting darker when moving from small (as25) to large aspecular angles.

Figure 3: Screenshots of the rendering on the iPad of color-only simulation of a flat metallic coating panel inside the virtual light booth at three different geometries.

In these two visual tests, we evaluated the capability of the rendering framework to reproduce the color flop effect of metallic coatings. A set of 15 metallic samples were selected. In the first test we evaluated the perceived color difference on flat and color-only rendered images against the physical flat metallic panels. We studied the intra-observer repeatability and the inter-observer reproducibility. We found that the intra-observer repeatability is 0.4 units, covering less than 7% of the total scale of 6 steps, and the inter-observer reproducibility is 0.78 units, thus covering 13% of the total scale. Both values are small enough to be smaller than the quantification limit of the scoring method. The inter-observer reproducibility is higher than the intra-observer reproducibility, which is expected since observers are more likely to agree with themselves than with others.

In the second test, observers evaluated the perceived color difference for curved and color-only rendered images by comparing them to the curved physical panels. The intra-observer repeatability for this test is 0.61 units, covering 10% of the total scale of 6 steps, and the inter-observer reproducibility is 0.68 units, thus covering 11% of the total scale. Both variabilities are similar to Each OTHER and smaller than the quantification limit of the scoring method.

For the evaluation of flat panels, the average observer accepted the match for 12 of the 15 samples (average acceptance: 80%), while the average observer accepted 14 from the 15 samples when curved panels are evaluated. Therefore, we find an increased average acceptance of 93% for curved samples as compared to 80% when flat panels are evaluated. From these results we conclude that observers are more tolerant for rendering the color flop of curved 3D objects than for flat objects, which can be related to the gradual variation in appearance of 3D objects and its complexity. This could be due to the fact, that a curved gonio-apparent surface includes various geometries at the same time and the resulting visual impression is continuous and much more realistic than the impression generated by a single geometry at once.

CONCLUSION

The rendering approach was found to well reproduce the color shift of effect coatings. Our rendering approach shows a high average value for the acceptance percentage, when visually assessing both flat and curved panels. We also found that observers are more tolerant when judging curved sample, with an average acceptance of 93% compared to the 80% for flat samples. This could be due to the fact that a curved gonio-apparent surface includes various geometries at the same time and the resulting visual impression is continuous and much more realistic than the impression generated by a single geometry at once.

In future work, we will extend our investigation to include accurate rendering of sparkle and graininess of effect coatings.

ACKNOWLEDGEMENTS

The authors thank the Spanish Ministry of Economy and Competitiveness (RTI2018-096000-B-I00). The authors also thank the Ministry of Economy and Competitiveness for the pre-doctoral fellowship (FPIBES-2016-077325).

REFERENCES

Pfaff, G. 2009. *Special Effect Pigments, in High Performance Pigments*. Wiley-VCH Verlag GmbH & Co. KGaA, 75-101.

Maile, F. J., G. Pfaff, and P. Reynders. 2005. Effect pigments—past, present and future. *Progress in organic coatings* 54(3): 150-163.

Klein, G. A., and T. Meyrath. 2010. Industrial color physics. Vol. 154. New York: Springer.

Kirchner, E., I. Van der Lans, P. Koeckhoven, K. Huraibat, F. M. Martínez-Verdú, E. Perales, A. Ferrero, and J. Campos. 2019. Real-time accurate rendering of color and texture of car coatings. In: *Proceedings of IS&T International Symposium on Electronic Imaging*, 076.1-5, https://doi.org/10.2352/ISSN.2470-1173.2019.14.COLOR-076.

Huraibat, K., E. Perales, E. Kirchner, I. Van der Lans, A. Ferrero, and J. Campos. 2021. Visual validation of the appearance of chromatic objects rendered from spectrophotometric measurements. *JOSA A* 38(3): 328-336. https://doi.org/10.1364/JOSAA.413890.

Kirchner, E., and W. Cramer. 2012. Making sense of measurement geometries for multi-angle spectrophotometers. *Color Research & Application* 37(3): 186-198.

Kirchner, E., I. Van der Lans, E. Perales, F. Martínez-Verdú, J. Campos, and A. Ferrero. 2015. Visibility of sparkle in metallic paints. *JOSA A* 32(5): 921-927.

Ferrero, A., J. Campos, A. M. Rabal, A. Pons. 2013. A single analytical model for sparkle and graininess patterns in texture of effect coatings. *Optics express* 21(22): 26812-26819.

Huraibat, K., V. Perales, E. Viqueira, E. Kirchner, I. Van der Lans, A. Ferrero, and J. Campos. 2019. Byko-Spectra effect light booth simulation for digital rendering tool. In: *Proceedings of the XII Congreso Nacional del Color*, R. B. Román et al., Editors. Linares, 45-48.