BYKO-SPECTRA EFFECT LIGHT BOOTH SIMULATION FOR DIGITAL RENDERING TOOL

Khalil Huraibat[1*], Esther Perales[1], Valentin Viqueira[1], Eric Kirchner[2], Ivo Van der Lans[2],

Alejandro Ferrero[3], Joaquín Campos[3]

[1]*Department of Optics, Universidad de Alicante, Alicante, Spain*

[2]*AkzoNobel Technology Group Color; Sassenheim; the Netherlands*

[3]*Instituto de Óptica, Consejo Superior de Investigaciones Científicas, Madrid, Spain*

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1. Introduction

Nowadays, digital visualization is very common in many areas, starting from cinema applications, gaming and shopping to be widely used on many industries such as automotive, architecture and interior design. Indeed, digital simulation of gonio-apparent coatings is a very active hot topic for optical metrology, color science, computer graphics, and visual perception since this type of coatings changes visual attributes such as color and texture, depending on illumination and viewing geometry. This effect is obtained by the presence of special effect pigments containing metallic, interference or pearlescent pigments producing a strong color variation with the illumination/viewing geometry which makes it complex to characterize its appearance [1-3]. The color of these coatings is characterized by their spectral Bidirectional Reflectance Distribution Function (BRDF) measured for several geometry combinations.

Therefore, rendering of three-dimensional objects covered by these coatings is a technological challenge, since accurate color representation requires a full BRDF covering a large number of geometries which means large amount of data to deal with [4]. The encoding and representation of gonio-appearance in computer graphics platforms is usually done by 3D rendering software packages, and by applying theoretical optical models of the interaction between light and matter. For this purpose, AkzoNobel Technology Group Color developed a new 3D rendering software based on OpenGL 3.0 ES (Embedded Systems), an open source graphics library to run on an iPad tablet (2017 edition) [5]. This visualization tool is a dedicated framework for rendering complex materials such as gonio-apparent coatings, gloss, sparkle and other textured materials on 3D objects. The rendering is based on a multi-spectral physics-based approach to represent the BRDF when rendering three dimensional objects.

A first step to get visual fidelity is to simulate the illumination scene. For this we selected the Byko-spectra effect multi-directional light booth (BYK-Gardner) shown in figure1. This light booth is particularly suitable for this task, since it was designed such as to optimize the visibility of sparkle and other texture effects in gonio-apparent automotive coatings with different luminaires. The first step is to build a 3D model of the lightbooth using Blender, an open source 3D rendering software widely used for digital simulation. Nevertheless, to achieve a realistic simulation of the light-booth, there are two important components that need to be well characterized. The first is the light source with its correct spectral emission and its angular distribution profile. The second is the walls and inner surfaces of the light booth surrounding the test object as they have influence on the final appearance of the test object. To characterize the light source, we developed a methodology to include the complete light emission characteristics of the light tubes, in order to be able to consider the bidirectional reflectance for any geometry of the coatings to be rendered. This methodology is based on measured illuminance levels inside the light booth. We built six different 3D models in Blender, one for each of the different geometries supported by this lightbooth, the 45as110, 45as75, 45as45, 45as25, 45as15 and 45as-15.

Therefore, the aim of this work is to build a complete rendered simulation of the Byko-spectra effect lightbooth. This simulated light booth will be used in the next phase of this work, to support psychophysical visual experiments on the rendering of virtual objects inside the virtual lightbooth and real samples inside the physical lightbooth to improve the visualization of 3D objects covered by effect coatings.

Figure 1: The Byko-spectra effect multi-directional light booth (BYK-Gardner).

2. Methods

The first step was to build a 3D model of the Byko-spectra effect lightbooth using Blender by defining its shape and the correct location of all its components. To construct the shape model, we used Blender. The lighting environment for the used rendering tool is specified in terms of the photometric files IES/EULUMDAT format which might be available from the manufacturer of the lightbooth or its luminaries. This enables the user to specify the luminous intensity distribution of the illumination on the reflective areas surrounding the object that needs to be rendered. Unfortunately, IES/EULUMDAT files of the light tubes inside the Byko-spectra effect light booth were not available from the manufacturer. We developed a methodology to describe the emission profile of the light tubes, in order to be able to consider the bidirectional reflectance for any geometry of the coatings to be rendered. The light source in the light booth (Philips Master PL L90 De Luxe 55W/950/4p) is simulated considering that it is composed by two separate tubes. To calculate its emission, we represent the two large tubes by N point sources along their length, where all points are assumed to have the same angular luminous intensity distribution, which needs to be determined. Under this assumption, the non-uniformity of the illuminance on the sample is produced by the near-field conditions of illumination. Inside the light booth, we measured illuminance at M positions on the sample plane of the booth [6]. In this approach, the measured value at a given position equals the sum of the illuminance contributions produced by each of the N point sources composing the light tubes. Each single illuminance depends on the relative position of each single point source with respect to the position on the sample plane, and it involves considering the angular position θ with respect to the normal to this plane. Under these conditions, and assuming a Gaussian angular luminous intensity distribution for the point sources, the best values for the Gaussian model parameters (sigma and luminous intensity at $\theta = 0°$) were obtained by fitting the modelled illuminances to the measured ones. For rendering purposes, Hietz *et al.* developed an algorithm to model polygonal light sources defined by a number of points [7]. By using this algorithm, the light tubes of the Byko can be accurately represented by a polygon composed of N points.

We also measured the spectral radiance of the light source and the spectral reflectance of the surrounding walls and surfaces. The next step is to combine all the data we have; the Blender file, the light spectrum, the light intensity distribution and the spectral reflectance of the walls by using the pre-processing to prepare the virtual environment of the Byko-spectra lightbooth to run on the 3D rendering tool using real-time OpenGL computations.

3. Results

A primary virtual model is prepared on the 3D rendering tool. The first attempt of the rendered lightbooth is shown in figure 2. It is still far from the real model since the light and walls characteristics are not included yet. From the results of the optimization, it is possible to conclude that the behaviour of the light source installed in the Byko-spectra effect multi-directional light booth is almost isotropic since it does not depend on the angle (extremely high sigma value for N = 100 and M = 55). Therefore, each of the N points emits isotropically with the same luminous intensity. By comparing theoretical and measured illuminance levels we find good accuracy with an average error of 10%, much smaller than the inhomogeneity of the illumination on the sample. After including the corresponding light spectrum, light distribution and the reflectance of the walls, a final version of the virtual lightbooth is obtained, and we are now able to simulate objects inside the virtual light booth as they would appear inside a real Byko-spectra effect light booth. Figure 3 shows an example of this rendering, where the distribution of the illuminance on a virtual curved sample (black half-sphere) in the lightbooth is shown. Figures 2 and 3 are just to show the inner parts of the rendered lightbooth and it doesn't match with what the observer sees during the visual experiments.

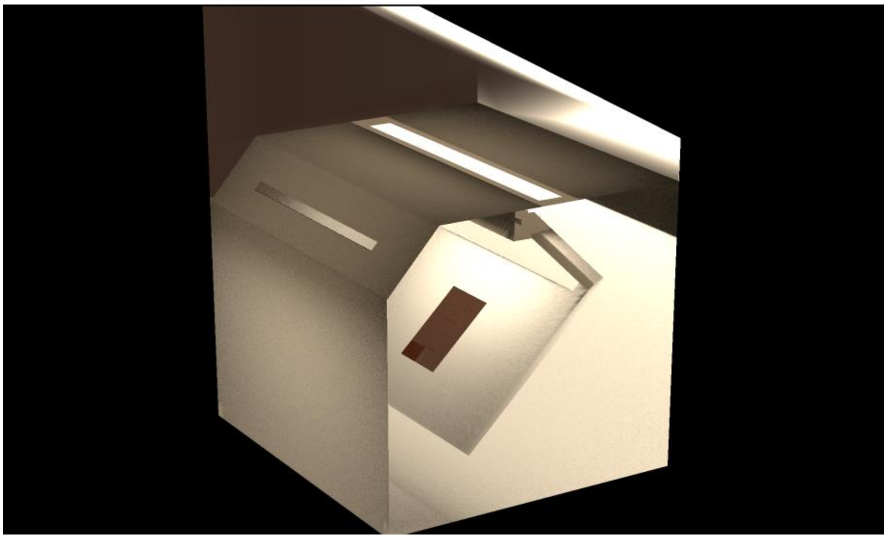

Figure 2: Tablet screenshot of the 3D rendering tool simulation of the Byko-spectra effect lightbooth (first attempt).

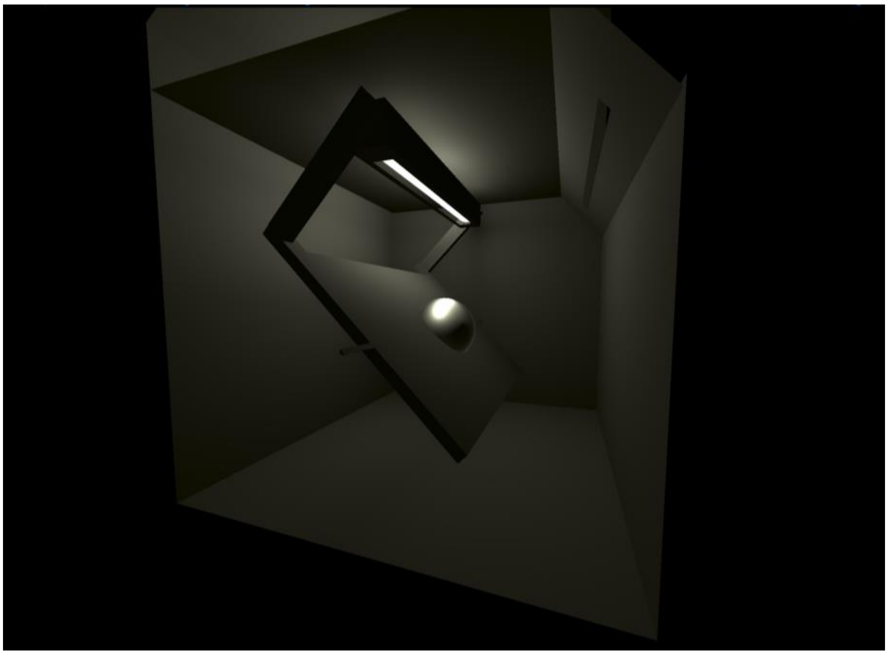

Figure 3: Tablet screenshot of the 3D rendering tool simulation of the Byko-spectra effect lightbooth (final version).

4. Conclusion

In this work, we built a virtual standardized illumination scene for visual assessment by simulating the multi-angle Byko-Spectra Lightbooth. A methodology to simulate a specific lighting scene is proposed. This methodology is based on the computation of the illuminance as produced by the sum of N point sources composing an extended source, assuming them to have a Gaussian angular luminous intensity distribution, which is characterized by comparison with measured illuminance values. This result simplifies the design of the lighting environment for the developed rendering tool. It shows that the light tubes can be accurately represented by a polygon composed of N points, and by using Real-Time Polygonal-Light Shading with the Linearly Transformed Cosines algorithm. A final version of the virtual light booth is created using OpenGL 3.0 ES. As a result, the rendered environment seems very similar to the real light boot and to the produced illumination. Further work by doing visual experiments comparing the behaviour of rendered objects covered by effect coatings and visualized inside the virtual lightbooth to the real objects inside the real lightbooth will be performed to test and then improve the visualization of such color effects.

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