A Computer Graphic System for Rendering Gonio-Apparent Colors

Gary W. Meyer, Harold B. Westlund, Peter A. Walker, and Joseph P. Wingard*

Department of Computer and Information Science
University of Oregon
Eugene, OR 97403

ABSTRACT

A computer graphic system has been developed that allows a color scientist to evaluate the appearance of gonio-apparent colors. Reflection modeling software is used to define a BRDF from existing computer graphic reflection models and standard appearance measurements for gloss and metallic travel. A visualization program allows the user to examine the BRDF that results from reflection modeling. Real-time software and hardware can be employed to adjust the BRDF and display a surface with the specified reflection properties. A high quality rendering system is available to make individual pictures that incorporate complex lighting and reflection effects.

Keywords: Color, Computer Graphics, Reflectance Modeling

1. INTRODUCTION

A system has been developed for making accurate computer graphic pictures of metallic and pearlescent automotive finishes. The system is different from other computer graphic rendering programs in that it characterizes surface reflection by using industry standard gloss and multi-angle spectral measurements of gonio-apparent surfaces. These instrumental measurements are used to construct a bi-directional reflectance distribution function (BRDF) that models both the color and the spatial distribution of the light reflected from a surface. The system includes a visualization tool that allows the analyst to see the shape of the BRDF at a variety of different incidence angles. The appearance of a dynamic object, to which the BRDF has been attached, can be seen by using recently developed real-time shading techniques. In addition, a public domain rendering program has been extended to produce static pictures of objects with metallic or pearlescent BRDF's in complex lighting environments.

2. BRDF VISUALIZATION

The spatial distribution of the light reflected from an object's surface plays a key role in determining the appearance of that object. To assist in evaluating the shape of the reflectance distribution, a BRDF visualization tool was developed as part of the system for rendering gonio-apparent colors. The BRDF to be displayed could be the result of making a surface reflection measurement with a gonio-photometer. The BRDF could also be generated by evaluating an analytically defined reflectance function. A software library of such reflection models from within the field of computer graphics is available as part of the system.

The BRDF visualization tool was created using a commercially available visualization package from Advanced Visual Systems (AVS) called AVS Express. Express utilizes a dataflow paradigm in which the user employs a network editor to route data through modules specifically created for the visualization application. Each module performs a transformation on the data which is ultimately passed to a final three dimensional viewing module. Example pictures produced by the BRDF visualization tool are shown in Figures 1 and 2. The user can select different reflection models, change the direction of the incoming light, modify parameters for the reflection models, and alter the color, transparency, and resolution of the reflectance distribution.

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* Further author information:
G.W.M.: E-mail: gary@cs.uoregon.edu
H.B.W.: E-mail: westlund@cs.uoregon.edu
J.P.W.: E-mail: joseph@cs.uoregon.edu

3. APPEARANCE BASED REFLECTION MODELING

The most important part of the system is the construction of a BRDF from gloss and multi-angle spectral measurements.[1] A "virtual glossmeter" has been used to find the correspondence between standard gloss measurements[2,3] and the parameters of an existing computer graphic reflection model.[4] Given the source aperture for a standard glossmeter, the virtual glossmeter subdivides this aperture and evaluates the computer graphics reflection model using light incoming through one of the subdivisions. Integration across the detector aperture computes the gloss for this small portion of the source aperture. Repeating this process across the entire source aperture and summing up the component gloss values produces one data point for a function relating standard gloss to the parameters of the reflection model.

Multi-angle spectral measurement at three critical aspecular angles has been proven sufficient to characterize the "flop" of metallic and pearlescent paint.[5,6] A BRDF to model this subsurface reflection was constructed by interpolating the three aspecular measurements with second order polynomials. The cross section of the specular lobe was assumed to be symmetrical allowing these in-plane polynomials to be used to determine the out-of-plane portions of the BRDF. A BRDF produced in this manner for a blue metallic paint is shown in Figure 1. If this paint has a clear coat with gloss of 10, the first surface BRDF produced using the virtual glossmeter must be combined with the subsurface BRDF generated from the interpolating polynomial. The result is shown in Figure 2.

4. REALISTIC RENDERING

Creating a photorealistic computer graphic picture of the gonio-apparent surface is the final step in the rendering process. The reflectance properties of the surface, including both first surface gloss and subsurface flop effects, are determined by the BRDF. Recent developments in real-time shading make it possible to display objects with arbitrary BRDF's using consumer level PC graphics cards.[7,8] A program that utilizes the separable transform approach of Kautz and McCool has been integrated into the gonio-chromatic rendering system. To adjust the BRDF that is used by the real-time shading program, an interactive application has been developed that allows manipulation of the aspecular measurements that determine the flop of a metallic or pearlescent paint (Figure 3).

While gonio-chromatic objects may be rotated in real-time using the above programs, only limited global illumination phenomena can be simulated. To incorporate area light sources and complex inter-reflections a more sophisticated rendering program is required. The public domain Radiance program[9,10] has been modified so that it can make pictures of objects with complex BRDF's, including those that model gonio-apparent surfaces. Figures 4 and 5 show metallic and pearlescent colors that were produced using the modified Radiance program and BRDF's that incorporate gloss and flop effects.

5. CONCLUSIONS

Taken together, the components of this system make it easy for a color scientist to explore the appearance of new and existing gonio-apparent paints and surface coatings. Starting with a set of real or hypothetical multi-angle measurements, the analyst can interactively adjust individual data points or the entire reflectance distribution using the program shown in Figure 3. After specifying a gloss for the first surface reflection, the reflectance model in Section 3 can be employed to determine the spatial distribution of the reflected light. The shape of this BRDF can be examined using the visualization tool shown in Figures 1 and 2, and the appearance produced by the BRDF can be displayed in real-time using techniques mentioned in Section 4. After several quick iterations, a high quality final rendering can be made that includes complex lighting and inter-reflection effects.

This system illustrates that computer graphic hardware and software have now advanced to the point where computer aided color appearance design is possible.[11] In the 1960's, computer graphic terminals first demonstrated that it was feasible to display the outline of three-dimensional objects in real-time. This led to the development of computer aided geometric design techniques that are currently used by engineers, architects, and other designers. Within the last ten years the same real-time computer graphic capability has been developed for the display of complex surface reflection. As shown in this paper, these advances in computer graphic rendering can provide color scientists with computer aided color appearance design tools similar to those available in the geometric design field for over thirty years.

ACKNOWLEDGMENTS

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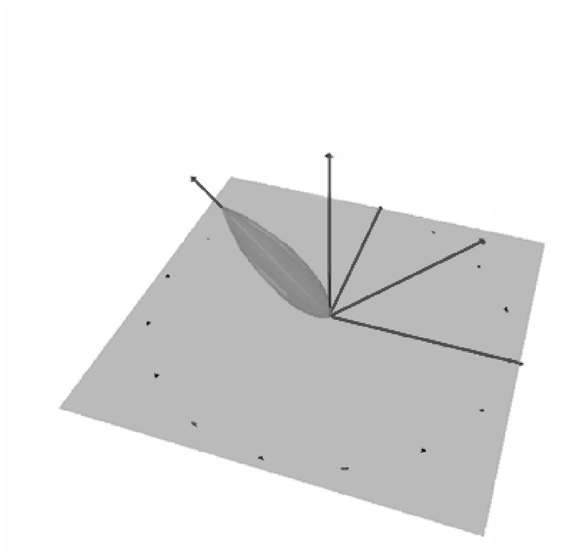

Figure 1. BRDF for a blue metallic paint.

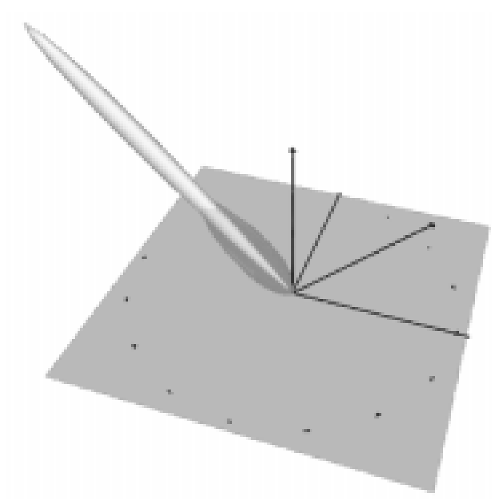

Figure 2. BRDF for a blue metallic paint with ASTM standard gloss of 10.

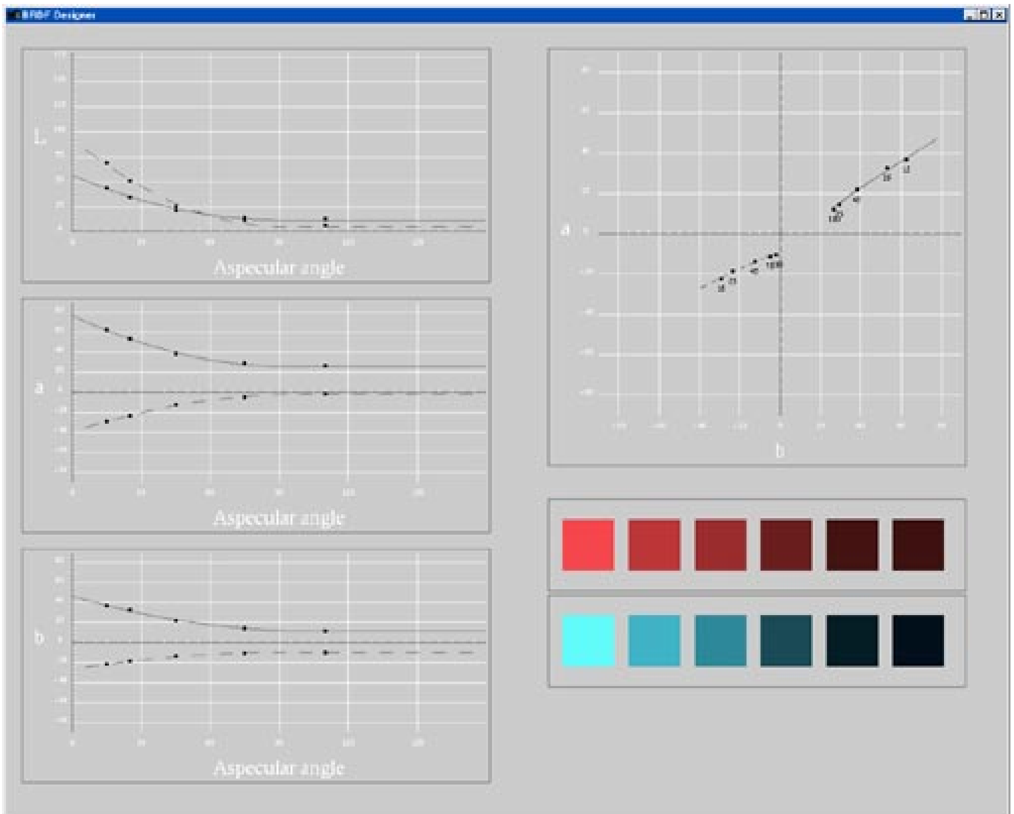

Figure 3. Interactive program used to plot and make adjustments to aspecular measurements.

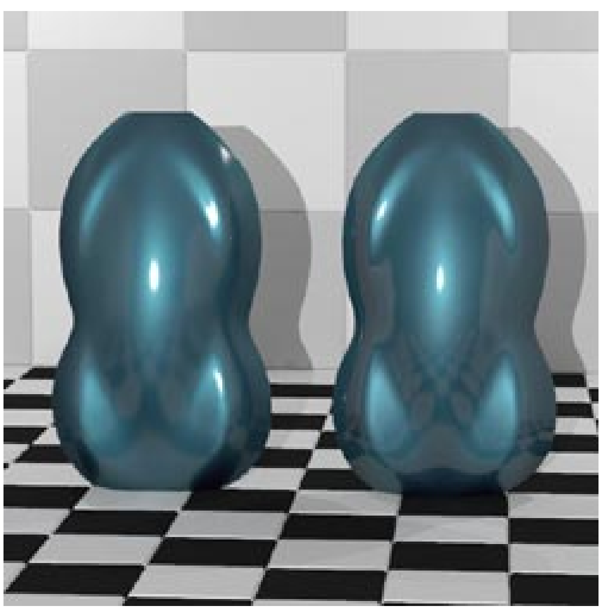

Figure 4. Gloss of 10 (left - same BRDF as Figure 2) and 60 (right).

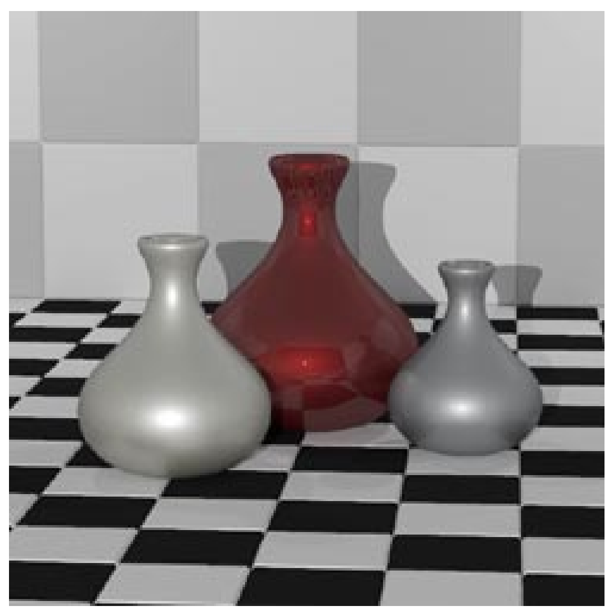

Figure 5. Pearlescent (left) and metallic (middle and right) colors.