EFFECTS OF MESOSCALE TEXTURE ON APPARENT SURFACE GLOSS

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ABSTRACT

In the paint industry, differences in application methods can lead to what is known as the “touch-up problem”, where two regions coated with exactly the same paint look different in color, gloss, or texture. In this paper we investigate the causes of the touch up problem and identify the physical and visual factors that contribute to it. We first measure both the microscale reflectance properties and mesoscale texture of flat, latex painted surfaces. Next, we fit BRDF and surface geometry models to these data. Using these models we then render physically accurate synthetic images of painted, touched-up surfaces. We are currently using these images as stimuli in perceptual experiments to systematically study how surface mesoscale properties, iillumination conditions, and vision interact to produce surface appearance differences.

Keywords: material appearance, gloss, texture, perception

1. INTRODUCTION

In the paint industry differences in paint application methods can produce mesoscale surface textures that cause the “touch-up problem”, where two coats of paint, a base coat and a top, touch-up coat, look different in appearance even though the paints used are exactly the same. The touch up problem may manifest itself as differences in color, gloss, and/or texture between the base and touch-up regions and the differences can vary with surface illumination and viewing conditions.

Figure 1 shows an example of the touch up problem. Here during construction, a wall in an office hallway was spray painted with a base coat of matte white paint. Over time spots on the wall were damaged and a touch-up coat of the same paint was applied locally with a fabric roller. When the wall is viewed straight on, the base and touch up regions match reasonably well. But when the wall is viewed obliquely with grazing illumination (as is often the case in a hallway), the base and touch-up regions differ significantly in appearance, clearly revealing the repairs and reducing the perceived quality of the repair job. In architectural applications, the touch up problem is a significant and costly problem for both the paint and construction industries, The problem extends to other fields as well, such as automotive manufacturing and repair.

Figure 1. The touch-up problem. The left panel shows a section of a white, matte painted wall viewed straight-on. The right panel shows the same section of the wall viewed obliquely. Note the differences in surface lightness and gloss in the base and touched-up regions.

In this paper we analyze the effects of mesoscate texture on the touch-up problem. Our approach has four components: measurement, modeling, simulation, and perception.

- We first measure the microscale reflectance properties of flat painted surfaces using a gonioreflectometer. We also measure the mesoscale textures of the surfaces using photometric stereo methods.
- We then fit the reflectance data with the Cook-Torrance BRDF model and calculate surface normal maps to represent the mesoscale textures.
- Using these models we then render physically accurate synthetic images of the surfaces using computer graphics image synthesis techniques. Through computer graphics, we can vary the parameters of the models to produce systematic variations in paint color, gloss, and texture and we can

render images that show differences in the micro- and mesoscale reflectance properties of these paints under different illumination and viewing conditions.

- We then describe how we are using the rendered images as stimuli in a series of perceptual experiments to investigate how the surface appearance changes with variations in physical surface properties and environmental lighting and viewing conditions The results of these experiments can be used to to develop a psychophysical model of the touch-up problem that can be used to predict how differences in paint formulation and application methods affect severity of the problem, and to prescribe methods that can be used to minimize it.

2. METHODS

Sample preparation

Twelve touch-up samples were created by applying six different kinds of flat interior latex house paint to 2’ square panels of standard paper coated gypsum wallboard. Both airless spraying and backrolling were used to apply the base coats. Once the base coats had dried, 1’ square regions in the centers of the panels were “touched-up” with a second coat applied by backrolling. Thus we created the full sample set which consisted of 6 paints each represented by two panels (spray base/backroll touch-up, backroll-base, backroll-touchup).

Reflectance measurements

At the microscale level, surface reflectance can be described using the bi-directional reflectance distribution function (BRDF), which characterizes how the surface scatters incident light[1]. BRDF measurement of the base and touch-up regions of the samples were done using a Murakami GSP-1B gonio-spectrophotometer. In-plane measurements with source angles at 15, 30, 45, and 60 degrees were taken. The results for one sample (spray base, backroll touch-up) are shown in Figure 2.

In Figure 2a the open circles show the data for the base region. Note that the magnitude of the specular reflection (when detector angle equals source angle) increases with source angle due to Fresnel effects that cause an otherwise matte surface to appear glossy when viewed at grazing angles. Note also that the wide spreads of the distributions indicate even at grazing the surface is relatively low gloss.

Figure 2b shows the data for the touch-up region. Note that both the base and touch-up show the same basic behavior with change of source angle, but note also that each of the distributions in for the touch-up region are higher and narrower than those of the base region. This indicates that over the range of spatial scales measured by the Murakami instrument, the touched-up region is optically smoother than the base region.

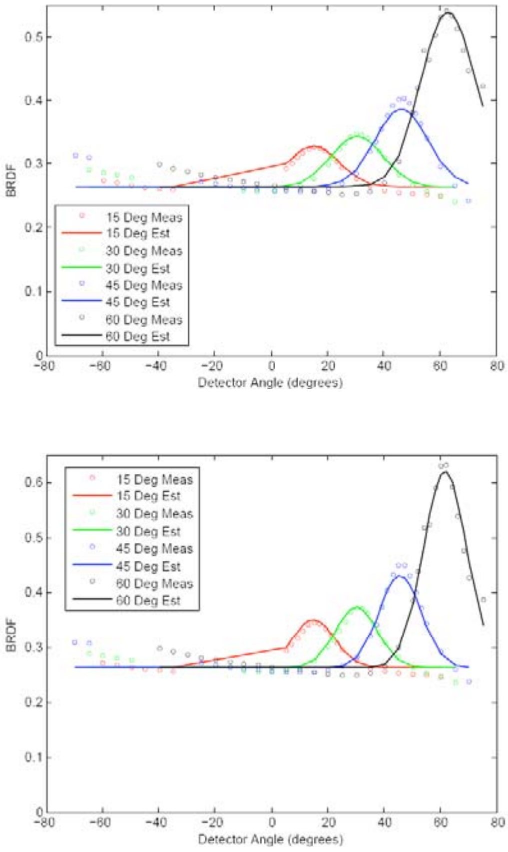

Figure 2. BRDF measurements for the a) sprayed base and b) backrolled touch-up regions for one sample.

Topographic measurements

In addition to the reflectance properties, significant information about the visual characteristics of a surface can be derived from its topographical features. Measurement of mesoscale surface texture was performed using photometric stereo to derive surface normal maps[2].

Four images of the sample were captured when it was illuminated from each of the cardinal directions (32° from the horizontal plane). The field of view of the camera was 36.8 mm so the measurement scale was approximately 0.07 mm/pixel.

A noise power analysis of the frequency distribution of the normal angles derived from the measurement was performed in order to characterize the distribution of the texture elements on the surface. The output was obtained in the form of a graph of the noise power of the base and touch-up regions (WBjj and WTjj respectively) versus frequency (ξjj) in cycles/mm (see Figure 3)

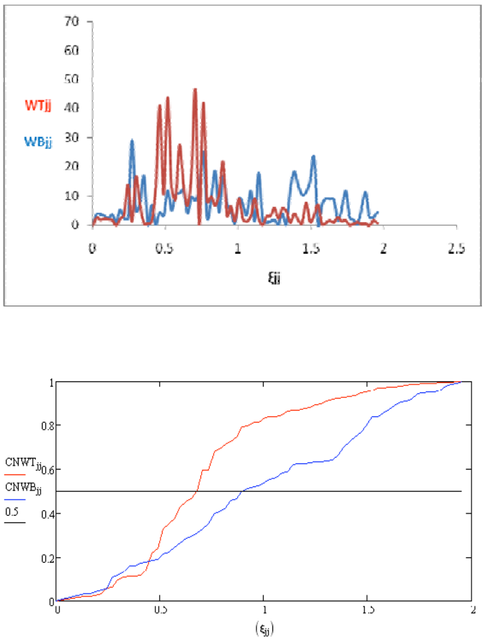

Figure 3 Top) Noise power spectra of the base (WB, blue) and touch-up (WT, red) regions. Note that the spectrum for the touch-up region is concentrated at lower spatial frequencies; Bottom) Cumulative noise power spectra for the base (WB, blue) and touch-up (WT, red) regions, The spectrum for the base is approximately linear (white noise-like) while the touch-up region has relatively more low frequency components._

Comparison of the two regions shows that the base region has a even distribution over a wide range of frequencies, while the touch-up region, which has an uneven distribution over a band of lower frequencies. The same phenomenon is reflected in the cumulative normalized noise power spectra (CNWBjj and CNWTjj) for the two regions.

This difference in energies between the two regions relates to the difference in visual appearance. At the mesoscale, the sprayed base region looks smoother and more finely textured than the backrolled touch-up region. It is interesting and curious to note that this is opposite to the result found for the BRDF measurements where the touch-up region was found to be smoother than the base region.

Modeling and Rendering

Using the BRDF data gathered in the measurement phase, we modeled the reflectance properties of the base and touch up regions using the Cook-Torrance light reflection model[3]. This model was used because of its effectiveness in handling diffuse materials, such as the paint samples. Also, the Cook-Torrance model does not assume peaks to be at specular angles like some of the other conventional models. The solid lines in Figure 2 graph below shows the fits obtained to the BRDF data using the Cook-Torrance model. Overall in the forward scattering direction (positive detector angles) the fits are good. Some backscattering effects (at negative detector angles) are not fit by the model but these are relatively minor.

Physically-based computer graphics rendering techniques were used to create photometrically accurate and visually realistic synthetic images of the painted samples. Geometric representations of the center-surround panels were created using the normal maps, material properties were set using the Cook-Torrance fits to the BRDF data and the resulting models were illuminated with a simulated point light source placed 10 feet away from the surface at an angle of 60 degrees from the surface normal.

Figure 4 shows synthetic images of the sample generated by this process. From left to right the images show the surface viewed at 0, 15 and 60 degrees with respect to the normal. At a normal viewing distance the scale of features in the images is equivalent to viewing the panel from a distance of approximately 3 feet. Note that the simulations faithfully capture the touch up phenomenon, where the base and touch up regions are indistinguishable at near-normal viewing angles, but where the touch up region looks glossier that the base when viewed from an oblique angle.

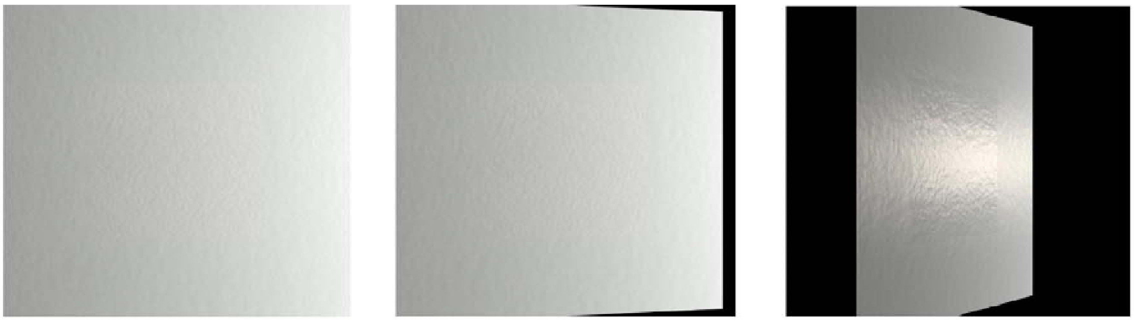

Figure 10. Renderings obtained with camera at 0° (left), 15° (middle) and 60° (right)

WORK IN PROGRESS

We are currently working to use the computer graphics techniques demonstrated above to generate stimuli for a series of perceptual experiments to study the relationships between surface reflectance, geometry, illumination, and viewing conditions and the visual qualities and magnitude of the touch up problem. In the experiments we are systematically varying each of these factors and analyzing how they affect the visibility of the touched-up regions. At the moment we are doing pilot work to understand the critical spatial scales that contribute most to the touch-up problem. To do this we are taking advantage of the power of computer graphics to separate effects due to BRDF from effects due to texture.

Preliminary results suggests that BRDF differences contribute most to the touch-up problem, however this also raises the issue of how texture and BRDF measurements relate to each other, since due to its large acceptance angle, the sensor in the gonio-photometer is incorporating the effects of mesoscale texture variations into its BRDF estimates. We are teasing these effects apart in the experiments and determining the critical visual spatial scales that contribute most to the touch-up problem.

Using the results of the perceptual experiments we should be able to build a psychophysical model of appearance for painted architectural surfaces that will relate the physical properties of the surfaces to their visual appearances. This model can then be used to allow paint manufacturers, architects, designers, and contractors understand how and why the touch-up problem occurs, and to determine how to adjust formulations and/or application methods to minimize the problem.

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