Effects of microscale and mesoscale structure on surface appearance

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Real-world surfaces typically have geometric features at a range of spatial scales. At the microscale, opaque surfaces are often characterized by bidirectional reflectance distribution functions (BRDFs), which describe how a surface scatters incident light. At the mesoscale surfaces often exhibit visible texture – stochastic or patterned arrangements of geometric features that provide visual information about tactile surface properties such as roughness, smoothness, softness, etc.. These textures also affect how light is scattered by the surface, but the effects are at a different spatial scale than those captured by the BRDF. Normally both microscale and mesoscale surface properties contribute to overall surface appearance, however under particular illumination and viewing conditions, one or the other may dominate. In this project we investigated how microscale and mesoscale surface properties interact to determine perceived surface lightness. We measured the BRDFs and textures of flat surfaces covered with matte latex wall paints applied by spray or roller, then created computer graphics models of these surfaces and rendered center/surround targets with identical BRDFs but different textures. Observation of the images under directional lighting shows that as the viewing angle changes from normal to grazing, the lightness contrast of the center and surround regions change non-monotonically with the rougher textured surface first appearing lighter than the smoother one, then darker as the specular angle is approached, then potentially lighter again near grazing. This complex behavior is due to both the surface physics and simultaneous contrast effects, and is the cause of the well-known “touch-up problem” in the paint industry. We have conducted psychophysical studies that characterize how the perceived lightness differences of surfaces vary with BRDF and texture properties, and are developing models that can predict lightness differences for various lighting and viewing conditions, and provide prescriptions for minimizing the effect.

Effect of Microscale and Mesoscale Texture on Surface Appearance

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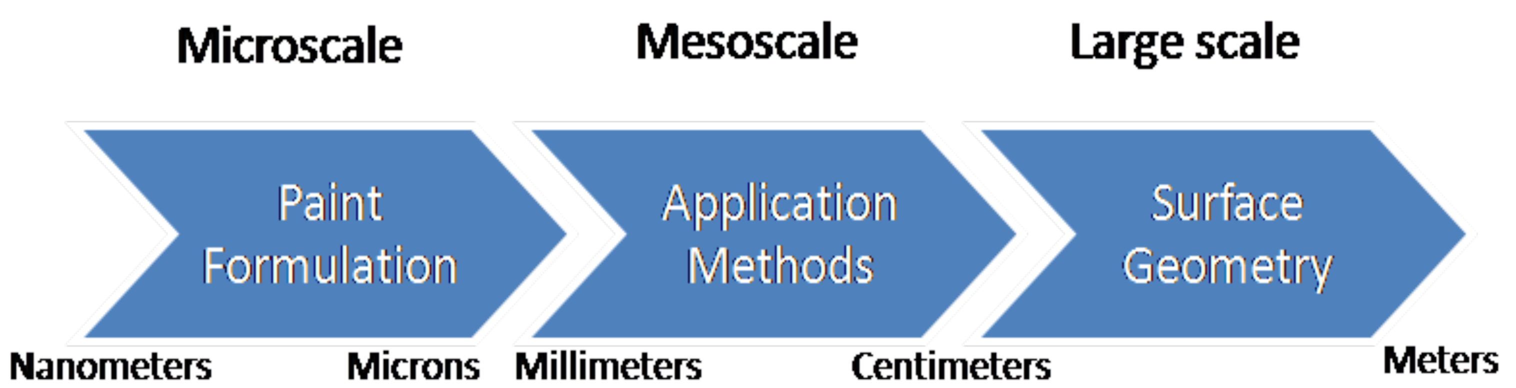
THE TOUCH – UP PROBLEM

In the paint industry, differences in application methods can lead to the "touch-up problem", where a base coat and a top, touch-up coat look different in appearance even though the paints used are exactly the same.

WHAT CAUSES THE TOUCH - UP PROBLEM AND HOW CAN ONE ADJUST THE FORMULATIONS AND APPLICATION METHODS TO MINIMIZE IT ?

INTRODUCTION

Paint is used as a surface finish in architectural applications
Consists of pigment particles suspended in liquid binder

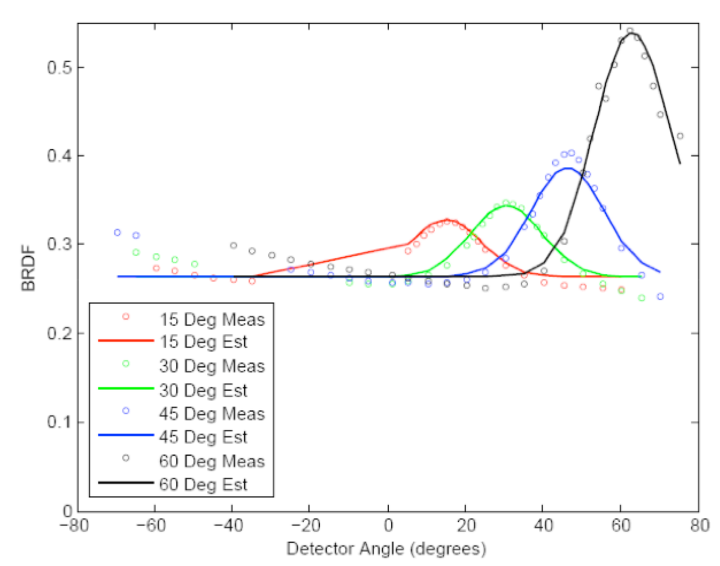


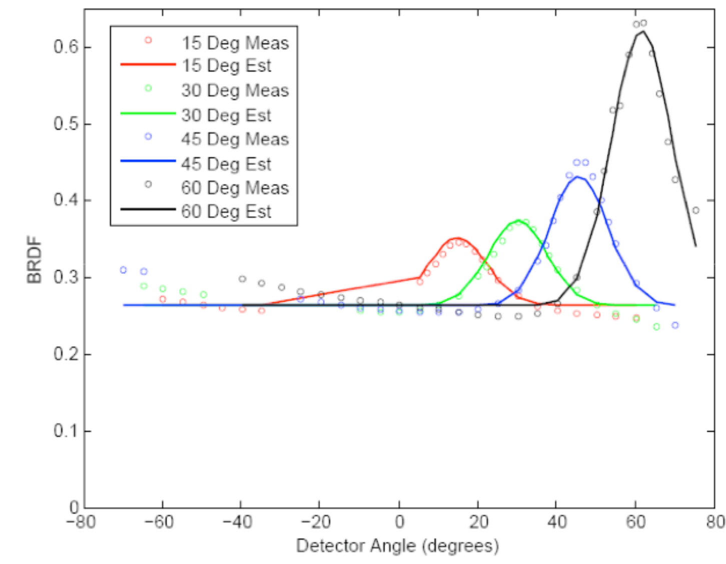
APPROACH

1. Measure surface reflectance properties – BRDF
2. Measure surface topography – mesoscale texture
3. Computer graphics modeling and rendering

REFLECTANCE MEASUREMENTS

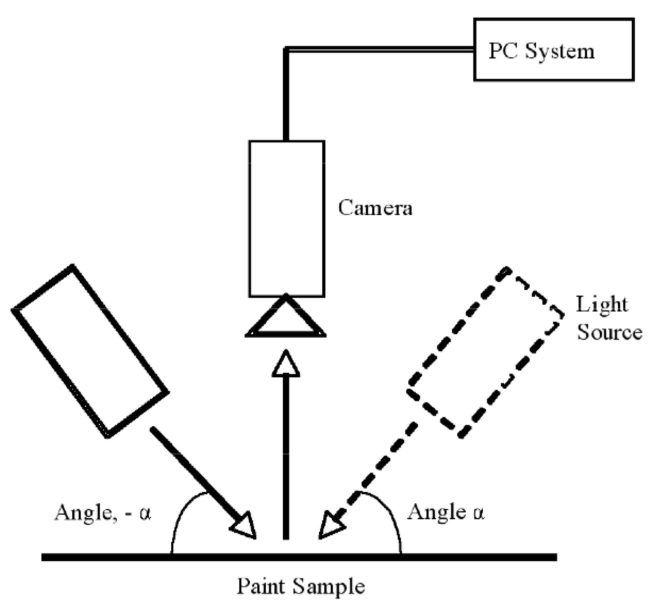
- BRDF describes how a surface scatters incident light
- BRDF of base and touch-up regions was measured using Murakami GSP-1B gonio-spectrophotometer
- In-plane measurements with source angles at 15, 30, 45 and 60 degrees were taken



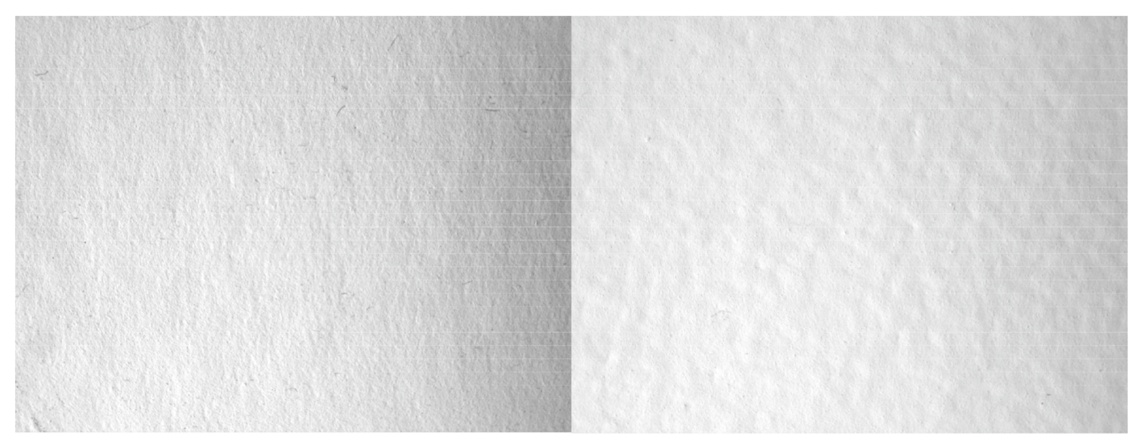


Magnitude of specular reflection increases with source angle due to Fresnel effects
Base and touch-up show same behavior with change in source angle, but distributions in touch-up are higher and narrower than base
Over range of spatial scales measured by the Murakami, the touched-up region is optically smoother than the base

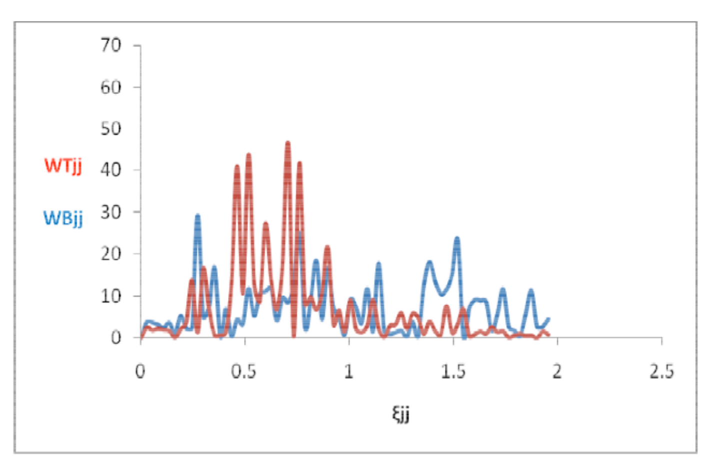
TOPOGRAPHIC MEASUREMENTS

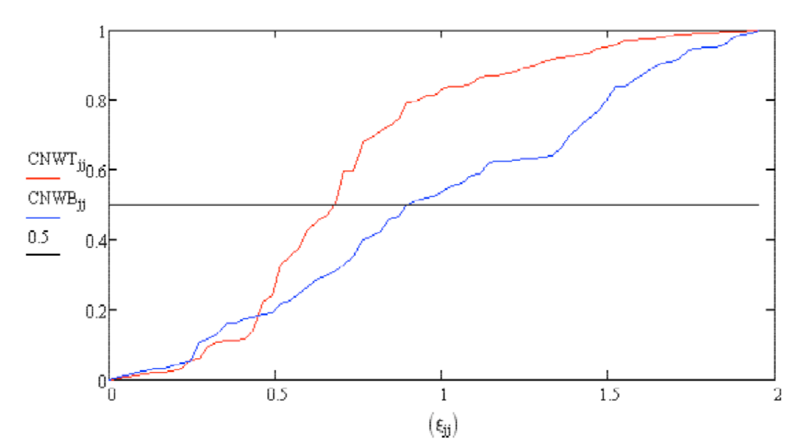


- Photometric stereo method was used to obtain surface normal maps
- Two images of sample were captured by illuminating it at equal and opposite angles
- Angle of illumination = 32°
- Field of View = 36.8 mm
- Scale = 0.07 mm/pixel



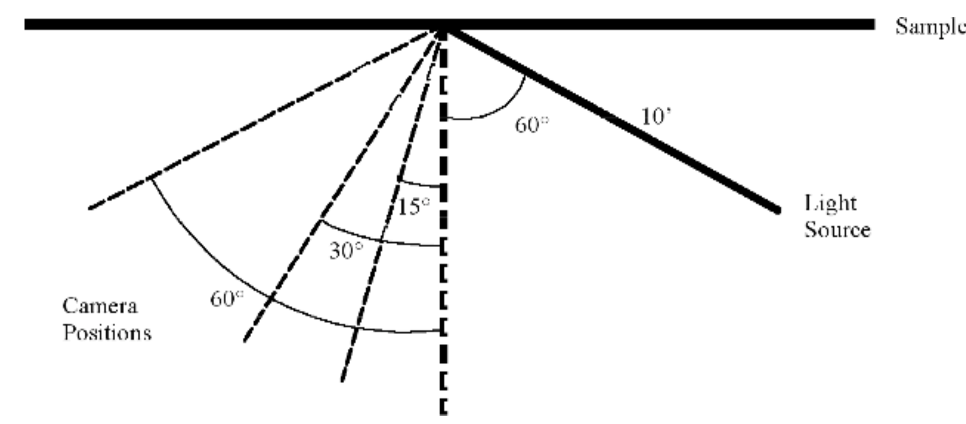
Noise power analysis was performed to characterize size of surface facets.
Base region showed even distribution over a wide range of frequencies; whereas touch-up had an uneven distribution over a band of lower frequencies.
At mesoscale level, sprayed base region looks smoother than backrolled touch-up





MODELING AND RENDERING

- Reflectance properties of base and touch-up modeled using Cook-Torrance light reflection model
- Minor backscattering effects are not fit by the model
- Computer graphics rendering techniques used to create photometrically accurate synthetic images



- At normal viewing distance, scale of texture in images is equivalent to an effective viewing distance of 3 feet from samples

PERCEPTUAL EXPERIMENTS

- Currently working toward generating stimuli for perceptual experiments to study relationship between surface reflectance, geometry, illumination, and viewing conditions and the quality and magnitude of the touch-up problem
- Need to understand spatial scales that contribute to the problem

Results suggest that BRDF differences contribute most to touch-up problem – due to a large acceptance angle, the gonio-photometer incorporates mesoscale texture variations into BRDF
Important to tease these effects apart to understand the scale

The ultimate goal is to build a psychophysical model of appearance for painted architectural surfaces that will relate physical surface properties to their visual appearance. This will help determine correct formulations and application methods that help minimize the touch-up problem