A Dynamic BRDF Display

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1 Introduction

Traditional computer displays are designed to be invariant to illumination and viewing conditions. However, this is not what the real world behaves like. Real materials reflect the surrounding light in a characteristic way that depends on the angles of illumination and observation.

We envision a future generation of devices that behave more like showcase windows through which the real and virtual worlds can interact with each other. To this end, it may become necessary to display the *reflectance* of materials, instead of fixed colors.

As a very first step towards this goal, we present a device that can display programmable degrees of surface roughness. The underlying principle is inspired by the microfacet theory. By exciting traveling surface waves, a liquid surface is deformed dynamically. The normal statistics of the resulting surface, averaged over time, can be controlled so as to follow an anisotropic Gaussian distribution. The reflectance displayed by our device is thus related to some of the most popular analytical models, including Ward's anisotropic BRDF [1992].

An in-depth treatment of the idea and theory behind our device is provided in [Hullin et al. 2011]. Our Emerging Technologies exhibit will showcase a revised and improved prototype of our BRDF display in action. In the associated talk, we will focus more on the "big picture", i.e., the general problem of dynamically displaying BRDFs, and we will outline various approaches to its solution.

2 Problem Definition

The long-term goal of our work is the creation of a device that can be programmed to look like different materials, e.g., like metal, plastic, chalk, etc., in the surrounding light and under all viewing conditions. In other words, we want to dynamically display a bidirectional reflectance distribution function (BRDF) on a surface. This implies a set of fundamental requirements that our device has to meet: First, of course, the surface of the device needs to reflect incident light into variable angular distributions. Its response must be immediate and deal with irradiance over a wide dynamic range. In order for the device to deliver a convincing viewing experience, its light efficiency should be comparable to that of real materials.

Given these requirements and the capabilities of today's imaging devices, any feasible implementation must be optically passive, i.e., the light path must not involve active components such as cameras and/or projectors. Since real materials reflect light in an optically passive way, we argue that it must be possible to build such a device.

There are two fundamentally different ways to approach the problem. [Fuchs et al. 2008] showed that high-dimensional reflectance fields can be encoded in *multiplexing* setups that provide a dedicated light path for every combination of incident and exitant light direction, and shape the distribution by multiplicative modulation. Such devices are inherently inefficient and limited in their resolution. On the other hand, [Weyrich et al. 2009] showed how light can be *redistributed* by carefully designed microgeometry, resulting in the desired reflection lobe. Our implementation follows this second, more natural, approach of redistributing the available light.

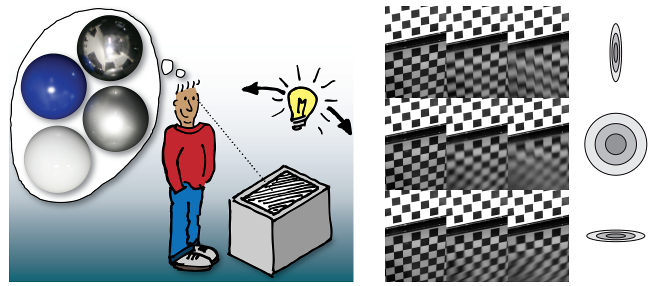
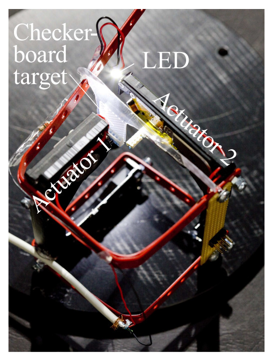


Figure 1: *Left: Idea of a BRDF display that mimics the reflectance of different materials and its variation with the illumination and viewing angle. Right: Reflections of a checkerboard pattern in the surface of our device at different anisotropic blur settings.*

3 Our Prototype



An earlier setup, consisting of a pair of used 2.5" hard disk arms. Checkerboard and LED are included for evaluation purposes.

Inspired by the scattering mechanism of real materials, we generate roughness by deforming a reflecting surface to achieve a desired normal distribution. Our device excites waves on a liquid surface, but other media could be imagined as well. The mechanics behind this principle are well understood [Hullin et al. 2011] and can be controlled to obtain a normal probability density function that follows an elliptical Gaussian lobe.

Our BRDF display (left) consists of components that can be obtained for less than U.S. $30: a microcontroller-based multichannel signal generator with amplification stage, actuators from used hard disk drives, a mounting frame and a receptacle filled with water.

References

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