# Literature Review -2

1. Practical Acquisition and Rendering of Diffraction Effects in Surface Reflectance.[Primary]
2. Real time Rendering of Realistic Surface Diffraction with Low Rank Factorisation.[Secondary]

Authors : ANTOINE TOISOUL and ABHIJEET GHOSH [Both Papers]

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## Abstract

The primary paper proposes 2 contributions for measurement-based rendering of diffraction effects in surface reflectance of planar homogeneous diffractive materials. A general solution for manufactured materials, they propose a practical data-driven rendering technique and a measurement approach to efficiently render complex diffraction effects in real time. Their measurement step involves photographing a planar diffractive sample illuminated with an LED flash. Furthermore, an efficient rendering method that exploits the measurement in conjunction with the Huygens-Fresnel principle to fit relevant diffraction parameters based on a first-order approximation. Their proposed data-driven rendering method requires the pre-computation of a single diffraction look-up table for accurate spectral rendering of complex diffraction effects and for sharp specular samples, They propose a method for practical measurement of the underlying diffraction grating using out-of-focus photography of the specular highlight.

The Cited paper presents a approach for real-time rendering of realistic diffraction effects in surface reflectance under environmental illumination.Renderings in arbitrary environments require the computation of a convolution. In the case of diffraction, the convolution kernel is large due to the high frequency details contained in diffraction patterns, making computations at real time frame rate impractical.The paper proposes a low rank factorization of the diffraction kernel that allows the computation of the convolution in two passes with smaller kernels instead of a large 2d kernel.


## Introduction

Diffraction effects can produce astonishing rainbow colors in surface reflectance. They happen when the micro geometry of a surface reaches a size close to the wavelength of light. When light is reflected by such a surface, light waves interfere and the angle of reflection becomes wavelength dependent. As a result white light is decomposed into its main colors. Stam was the first to propose a physically based diffraction BRDF derived from Kirchoff theory of diffraction. Although very accurate such a model cannot be used for real time renderings of arbitrary diffraction patterns as it relies on heavy computations at every frame of an animation.

Diffraction in surface reflectance is a complex optical phenomenon that presents two primary challenges for rendering: measurement and computation. They tackle these challenges by proposing practical measurement setups and efficient measurement-based rendering techniques for complex diffraction effects.

- A practical approach for direct measurement of diffraction effects in surface reflectance of planar homogeneous samples and a novel rendering technique to efficiently render.
- The approach relies on the Huygens-Fresnel principle in conjunction with a first-order approximation and can enable full spectral rendering and simulate complex light sources using efficient pre computation.
- A optical setup to practically observe the diffraction grating of highly specular planar samples using a DSLR camera equipped with a standard zoom lens.

Toisoul and Ghosh have proposed a reformulation of Stam's BRDF using a first order approximation as well as a measurement setup to directly measure diffraction patterns on homogeneous planar surfaces. their measurements are carried out at a single wavelength, and their method is able to recover the diffraction pattern under an arbitrary light spectrum. The result is stored in a diffraction lookup table that can be used for real time renderings under point light sources as well as arbitrary illumination using a pre-filtering method based on a convolution. As a result correct renderings of diffraction can be produced under arbitrary rotations about the view vector.

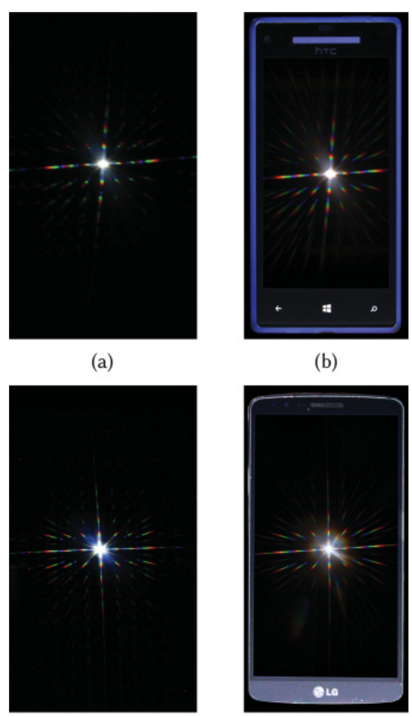
## Data-Driven Reflectance

### 1. Huygens-Fresnel Principle and Irradiance

They first derive an expression for the irradiance of a diffraction pattern based on the well-known Huygens-Fresnel principle. The principle states that any point on a wavefront acts as a secondary source and emits a new spherical wave with the same frequency, amplitude, and phase as the original wave, and these new spherical waves all sum up to create the wavefront at a later time.Hence, in the case of reflection on a diffractive surface, each point P(x, y) creates a spherical wavelet whose contribution has to be summed up over the entire surface.

### 2. Rendering Model

Their rendering approach takes into account the diffuse, specular, and diffractive components of the BRDF separately.For rendering reflections on regular surfaces, they compute the diffuse and specular components using a standard geometric optics BRDF model for isotropic reflections. For rendering diffractive surfaces, employ a simplified diffraction model based on a first-order approximation.Such a diffraction term can be calculated efficiently in real time by precomputing Sd into a look-up table and accessing it as a texture in a GLSL fragment shader. The calculations are done in the XYZ color space to accurately take into account the spectrum of the light source in the scene. They employ this formulation to index the Sd look-up table in a fragment shader for their data-driven



(a) (b)

(c) (d)

BRDF model.
Their measurement approach simply employs a regular DSLR camera equipped with a standard zoom lens for high-resolution imaging of the bokeh and a point light source for illuminating the sample surface. In this case, they equip the camera (Canon 650D) with an entry-level 55mm–250mm zoom lens (Canon EF-S f/4-5.6 IS STM) that allows focus at a relatively short distance of 0.85m.1 they place the camera around 85cm from the sample and illuminate the shiny diffractive sample with a phone LED flash from a distance of around 3m.

This work builds on the recent work of Toisoul and Ghosh and employs their first order diffraction BRDF model.The main component of the BRDF is the diffraction lookup table Sd that is computed from a measurement of the diffraction pattern at a single wavelength.

For rendering, they use the diffraction lookup tables. Each table can be parametrized by the non normalized half vector ® h = ® !i + ® !o where the horizontal and vertical axis of the table correspond to the projection of h onto the tangential coordinate frame Åt ; n t º. the convolution is then computed.then convolve the environment map in two passes using the two low rank filters obtained In each pass, first calculate projection of h plane and rotate it depending on the local orientation of the tangent in the second paper.

3. Rank Factorization

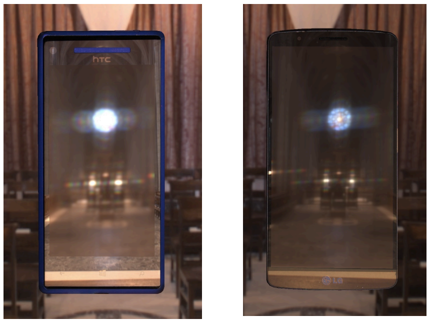
$$\begin{aligned} \arg \min_{\tilde{S}_d} \quad & \|S_d - \tilde{S}_d\|_F \\ \text{subject to} \quad & rank(S_d) = r \end{aligned}$$

The diffraction lookup table Sd can be factorized into an outer
product of two matrices of a lower rank r . .is factorization corresponds
to solving the following optimization process :

Results :

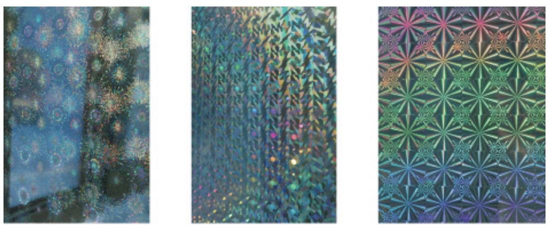

(a) (b)

The primary paper presents some diffraction patterns rendered with data-driven rendering approach. The renderings were computed assuming a full white illumination spectrum but can be calculated for any spectral distribution. The two smartphones exhibit different diffraction patterns that are accurately rendered.The basic reflectance maps for the two phones were measured using polarized second-order gradient illumination emitted by a desktop LCD panel. Unlike the phone screens, the holographic paper is rough specular, making wider lobes of diffraction.



They present renderings in the Grace Cathedral environment using a rank 1 factorization.The CD rendering is computed using single pass 1D convolutions in the direction of the local grooves. The TV rendering is modeled as the sum of two 1D convolutions (single pass) in the main directions of the diffraction pattern. Reach around 100 FPS at a resolution of 1920x1080 with a NVIDIA GTX 1080 GPU for these renderings.

Limitations :



(a) (b) (c)

Their proposed data-driven approach can accurately and efficiently render diffraction effects on many common smooth planar surfaces. However, since the method relies on direct measurement of the diffraction pattern on the surface, it is not as well suited for finely textured or spatially varying diffractive surfaces such as various kinds of holographic papers with printed patterns. In such materials, it can become difficult to automatically separate the observed diffraction pattern from the surface texture pattern for building the look-up table.