RECONSTRUCTION OF SPARSE HYPERSPECTRAL BRDF MEASUREMENTS PRESERVING THEIR PHYSICAL AND TOPOLOGICAL PROPERTIES

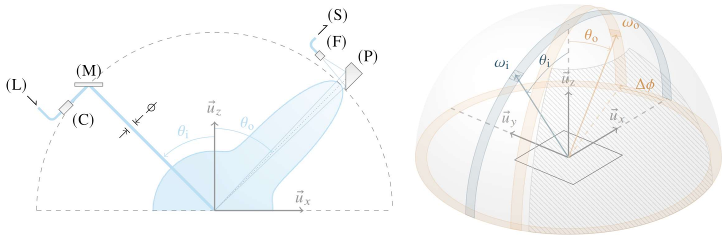
F. Margall[1,2,3], R. Ceolato[1], E. Coiro[2], S. Mavromatis[3] and R. Pacanowski[4]
[1]DOTA, ONERA, Université de Toulouse, Toulouse, France
[2]DOTA, ONERA, Salon-de-Provence, France
[3]Aix-Marseille Université, CNRS, LIS, Marseille, France
[4]INRIA, France

EUROGRAPHICS CONFERENCE 2024

INTRODUCTION

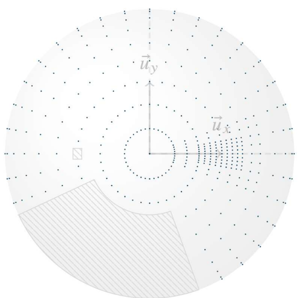
The measurement of hyperspectral bidirectional reflectance distribution functions (BRDF) is a key element in physically based hyperspectral rendering. While high spectral definition is guaranteed, angular sampling is more sparse. Here we propose a method for reconstructing the BRDF from scattered data.

MEASUREMENT SETUP



The setup consists of two controlled arms, one carrying a supercontinuum laser, the other a spectrometer. The spectral definition ranges from 450 to 1100 nm with a step size of less than 1 nm. The solid angle of observation is $d\omega_o = 9{,}77 \cdot 10^{-4}$ sr. The maximum observation angle is 89.3°.

SPARSE MEASUREMENTS



Several blind zones exist, such as backscatter, grazing angles, or a zone outside the plane of incidence, most of which result from mechanical constraints, with one arm obscuring the other.

Depending on the angle of incidence, the observation directions are sampled by delimiting three overlapping zones, centered around the specular direction, the most central being the densest.

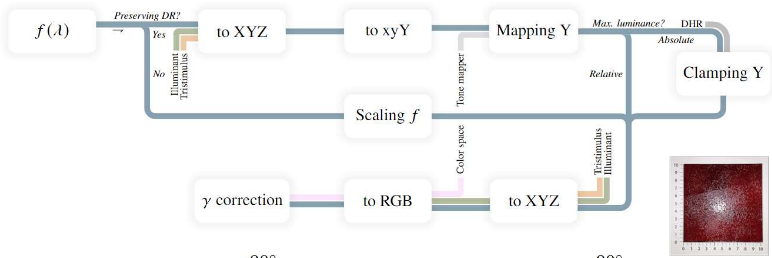
INTERPOLATION IN A $\mathbb{S}^2_+ \times \mathbb{S}^2_+$ MANIFOLD

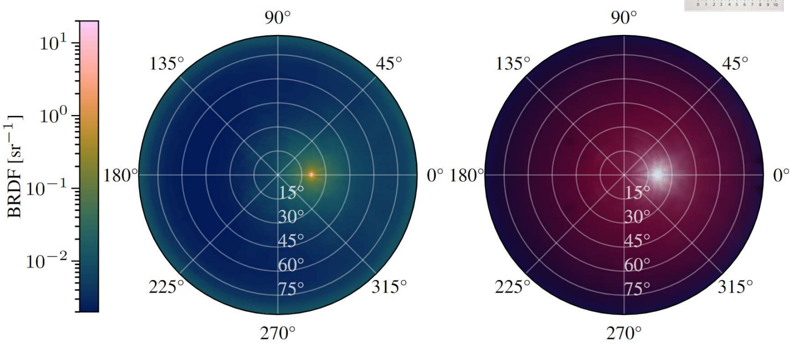
We define BRDF domain Ω as the Cartesian product of two unit hemispheres (each being the domain of the directions of incidence ω_i and observation ω_o respectively). This allows us to define a metric d_Ω associated to the domain Ω.

$$\Omega = \mathbb{S}^2_+ \times \mathbb{S}^2_+ \qquad d_\Omega((\omega_i, \omega_o), ((\omega_i', \omega_o'))) = \sqrt{d^2_{\mathbb{S}^2_+}(\omega_i, \omega_i') + d^2_{\mathbb{S}^2_+}(\omega_o, \omega_o')}$$

d_Ω can be specialised by folding the manifold in order to respect Helmholtz's principle of reciprocity ($f(\omega_i, \omega_o) = f(\omega_o, \omega_i)$). It is then used in a method of interpolation using radial basis functions.

FROM HYPERSPECTRAL DATA TO RGB VISUALISATION

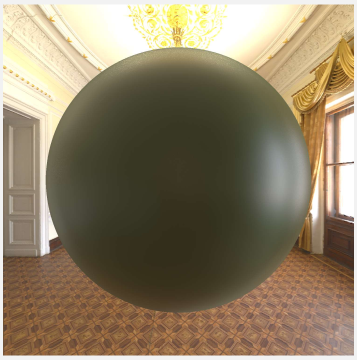




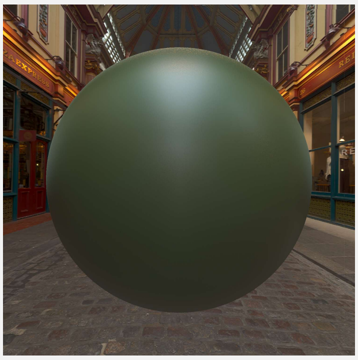
RESULTS

The interpolation method used allows us to obtain a complete BRDF, respecting the physical properties of Helmholtz non-negativity and reciprocity. The directional hemispherical reflectance calculated from the interpolated results obtained corresponds to that measured from the sample.

Vehicle paint used, measured and then interpolated, with the results shown on the right.



Ball room
Medium contrast – Natural & artificial light

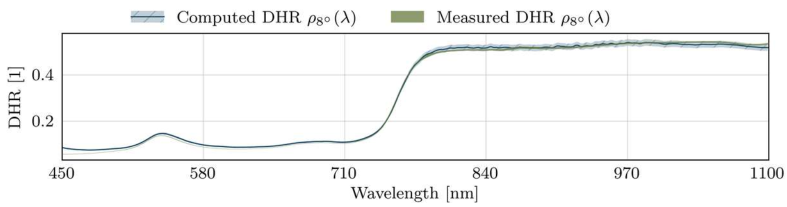


Leadenhall Market
High contrast – Natural & artificial light

Meadow
Low contrast – Natural light

CONCLUSION

The reconstruction method used enables us to obtain a complete dataset that can be used in a rendering engine. The properties of the reconstructed result, such as directional hemispherical reflectance (DHR), are consistent when compared with values measured using a spectrophotometer (on the right).



RÉPUBLIQUE FRANÇAISE — ONERA THE FRENCH AEROSPACE LAB — RÉGION SUD — Université de Toulouse — Aix Marseille université — cnrs — LIS LABORATOIRE D'INFORMATIQUE & SYSTÈMES — Inria