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Shape and Refractive Index from Single-View Spectro-Polarimetric Images

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Abstract In this paper, we address the problem of the simultaneous recovery of the shape and refractive index of an object from a spectro-polarimetric image captured from a single view. Here, we focus on the diffuse polarisation process occuring at dielectric surfaces due to subsurface scattering and transmission from the object surface into the air. The diffuse polarisation of the reflection process is modelled by the Fresnel transmission theory. We present a method for estimating the azimuth angle of surface normals from the spectral variation of the phase of polarisation. Moreover, we estimate the zenith angle of surface normals and index of refraction simultaneously in a well-posed optimisation framework. We achieve well-posedness by introducing two additional constraints to the problem, including the surface integrability and the material dispersion equation. This yields an iterative solution which is computationally efficient due to the use of closed-form solutions for both the zenith angle and the refractive index in each iteration. To demonstrate the effectiveness of our approach, we show results of shape recovery and surface rendering for both real-world and synthetic imagery.

Keywords Polarisation · Shape recovery · Refractive index · Spectro-polarimetric imagery · Multispectral imagery · Hyperspectral imagery · Fresnel reflection · Dispersion equations

1 Introduction

Polarisation measures the orientation of the electric field oscillations of light in the plane perpendicular to the direction of propagation. It has been widely utilised to develop powerful measurement and imaging techniques in various branches of physics including astronomy (Hall 1951), applied optics (Born and Wolf 1999; Mandel and Wolf 1995) and crystallography. Although the human vision system is insensitive to polarisation, a number of organisms including the Mantis shrimp, naturally possess a polarisation vision system (Marshall et al. 1991). In biology, researchers have also observed evidence for biophysical mechanisms of polarisation coding in various species of fish (Hawryshyn 2000). With recent advances in camera technology, polarisation effects can be captured by devices such as polarimeters and more recently, polarisation cameras (Wolff 1997; Wolff and Andreou 1995; Wolff et al. 1997). Wolff et al. (Wolff 1997; Wolff and Andreou 1995; Wolff et al. 1997) have developed a liquid crystal polarisation video camera. The key to this development is to use electro-optically controlled Twisted Nematic liquid crystals to replace the need for mechanically rotated linear polarisers. The development of

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