# Spectro-polarimetric BRF measurement of leaves and model of individual leaf

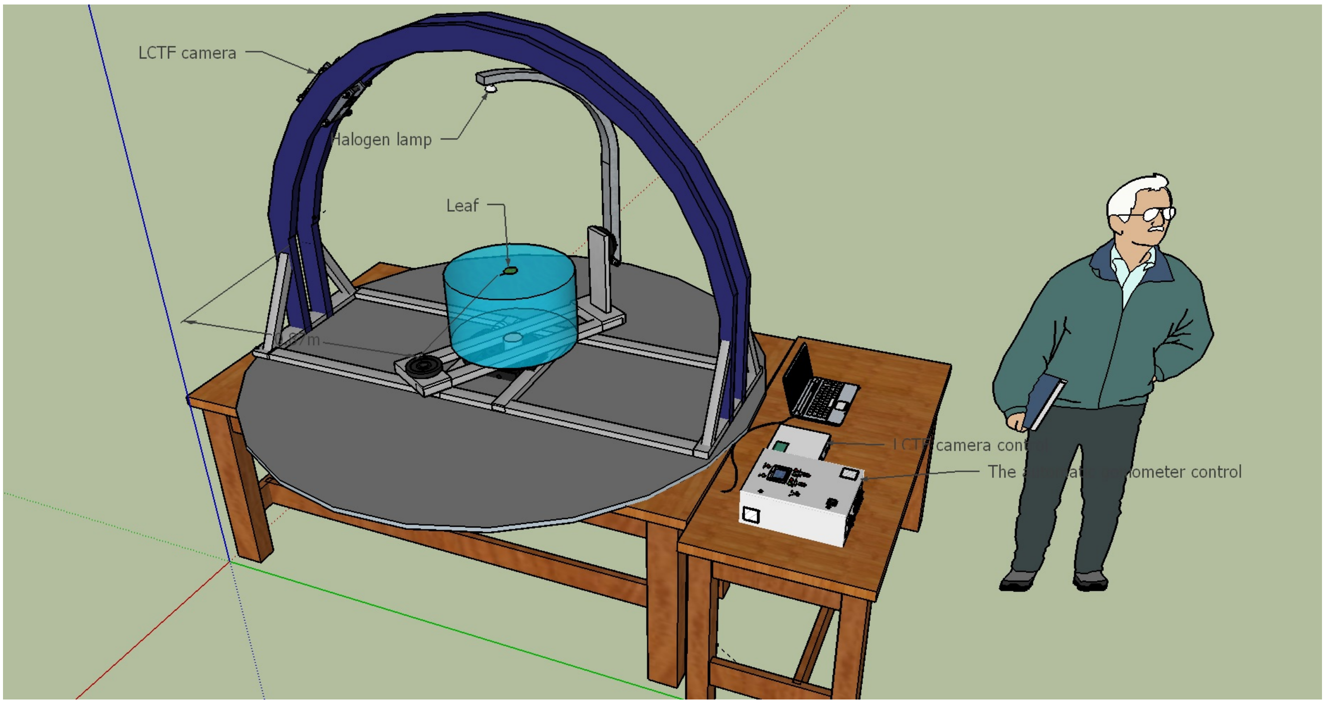
*Begzsuren Tumendemberel[1], Yukihiro Takahashi[1], Tetsuro Ishida[1], Junichi Kurihara[1], Nobuyasu Naruse[2]

1. Hokkaido University, 2. Shiga University of Medical Science

The reflectance of the leaf consists not only of its intensity but also of polarization, and the polarization techniques are generally used for separating specular reflectance from diffuse reflectance. The internal diffuse component of the spectral reflectance contains the details of the biochemical properties of the plant, an activity of photosynthesis, an expected amount of harvest, and water condition. Specular reflectance of the leaf strongly depends on a combination of the angle of incidence of the light source and the angle of observation view. The leaves look shiny at the shallow angle, where most of this reflection is polarized from the surface of leaves. Although the leaf spectral reflectance which is a point of convergence for many types of research, the study of spectral measurement with polarization in a single leaf is largely unexplored. To do this, the estimation of single leaf BRDF of Coffea canephora Pierre (Coffee), Epipremnum aureum (Pothos), and Fragaria ×ananassa (Strawberry) was carried out based on the measurements by Liquid Crystal Tunable Filter (LCTF) camera in the wavelength range of 460-780 nm with a linear polarizer. The imaging with the multispectral LCTF camera has a great advantage in measuring a selected leaf area with an arbitrary size of the field of view. There are hundreds of combinations of incident light and observation direction in single leaf Bidirectional Reflectance Factor (BRF) measurement. In order to conduct the measurements for all those conditions, we built the automatic goniometer with LCTF camera in a laboratory.
In previous studies, the leaf BRF prediction is usually based on the Cook-Torrance (Cook and Torrance, 1981) prevalent model in computer graphics assuming that the surface micro-geometry acts as a set of specular mirrors. Another type of models are widely used in the optics community, computing diffraction effects caused by differences in height in the surface micro-geometry and predicts visual appearance from the frequency content of the height distribution. The Cook-Torrance model may not be suitable for the leaf reflectance in our observation because the actual measurement cannot determine the surface roughness. The Generalized Harvey-Shack (GHS) scattering theory is well studied from rebound models determined by height distribution (Krywonos, 2006) and the GHS theory is not limited to any special wavelength range and RMS roughness value. Spectro-polarimetric measurement results and physical scattering theory have led us to create a new reflectance model. We successfully created a new leaf bidirectional reflectance model which considers that the diffuse component is Lambertian inside of the leaves and an internal scattering coefficient is calculated to an output value of PROSPECT model; the specular component is explained by GHS scattering theory. The polarization property of reflected light on a single leaf is also identified and rebuild bidirectional reflectance factors including polarized, unpolarized, and the total reflectance factors according to our model in this work. Finally, a new spectro-polarimetric bidirectional method is more controllable for the BRF pattern of a single leaf.

Keywords: BRDF measurement , Polarization, leaves , spectral


LCTF camera
Halogen lamp
Leaf