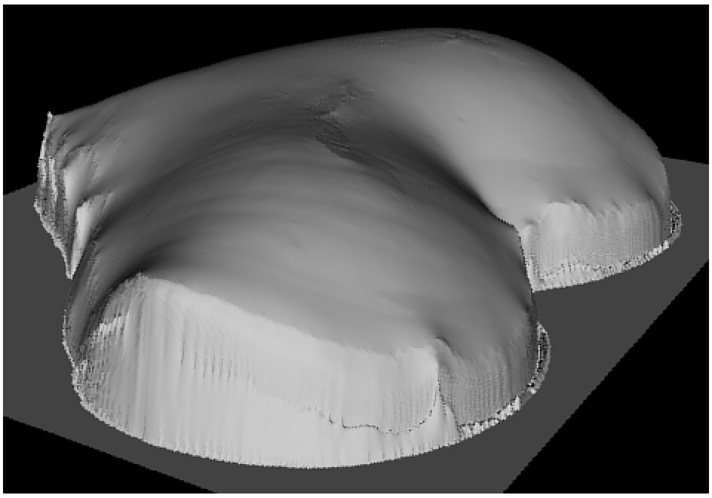
Daisuke Miyazaki, Masataka Kagesawa, Katsushi Ikeuchi,
"Polarization-based Transparent Surface Modeling from Two Views,"
in Proceedings of International Conference on Computer Vision,
pp.1381-1386, Nice, France, 2003.10

Polarization-based Transparent Surface Modeling from Two Views

Daisuke Miyazaki, Masataka Kagesawa, Katsushi Ikeuchi

ICCV proceeding pp.1381-1386

Real Image



Obtained Surface Shape

◆ Abstract

We developed a method to obtain 3D shape of object surface from the polarization state of reflected light on transparent objects observed from two views.

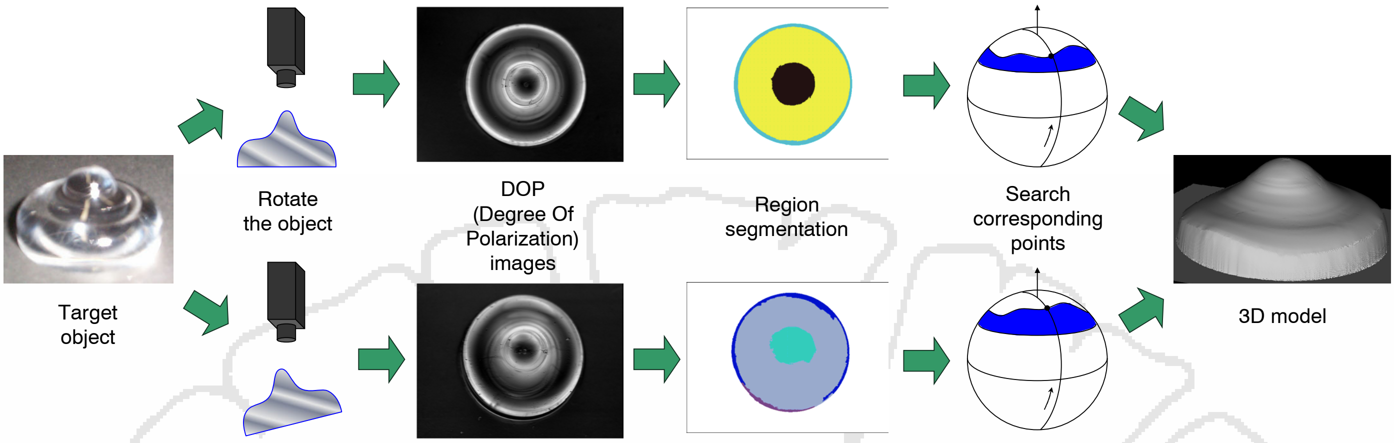
◆ Method

1. Measure the polarization state of the light reflected on the surface.
2. Rotate the object in a small angle, and again measure the polarization data.
3. Apply a region segmentation method to both two DOP(degree of polarization) data.
4. Detect a point which represent the same surface point in each region in each DOP data.
5. Determine the surface normal by comparing two DOPs taken before/after rotation at corresponding points.
6. Obtain the surface shape of transparent objects from the distribution of surface normal.

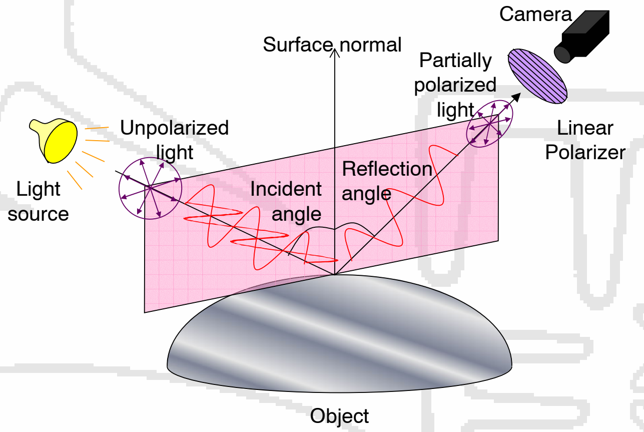
Transparent Surface Modeling Methods

	Approach	Number of viewpoints	Number of input images for each viewpoints		Disadvantage	vs	Advantage in our method
Murase 1990	Optical flow	1 viewpoint	Multiple images with different time		Only water wave	⇔	Solid objects
Hata et al. 1996	Pattern light projecting	1 viewpoint	Multiple images with different projected pattern light		Need calibration between camera and projector	⇔	No calibration needed
Ohara et al. 2003	Shape from focus	1 viewpoint	Multiple images with different focus		Only edged object	⇔	Smooth objects
Ben-Ezra & Nayar 2003	Shape from motion	Multiple viewpoint	1 image each		Only parameterized object	⇔	Many types of objects
Previous method [Saito et al. 1999]	Shape from polarization	1 viewpoint	1 polarization image		Ambiguity problem	⇔	Solved the problem
Previous method [Miyazaki et al. 2002]	Shape from polarization	1 viewpoint	2 polarization images	3 or more images for 1 polarization image	Need infrared camera	⇔	Only visible camera
Our method [Miyazaki et al. 2003]	Shape from polarization	2 viewpoint	1 polarization image each				

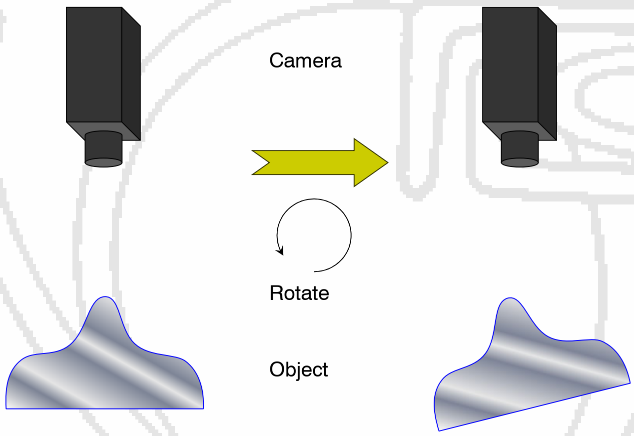
Outline



Reflection and Polarization



Rotating the Object



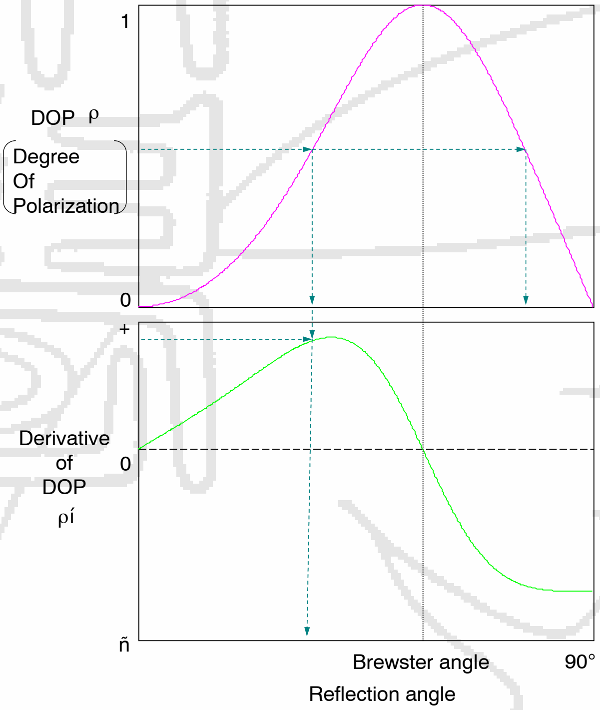
DOP (Degree Of Polarization)

$$\rho = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} = \frac{2\sin^2\theta\cos\theta\sqrt{n^2 - \sin^2\theta}}{n^2 - \sin^2\theta - n^2\sin^2\theta + 2\sin^4\theta}$$

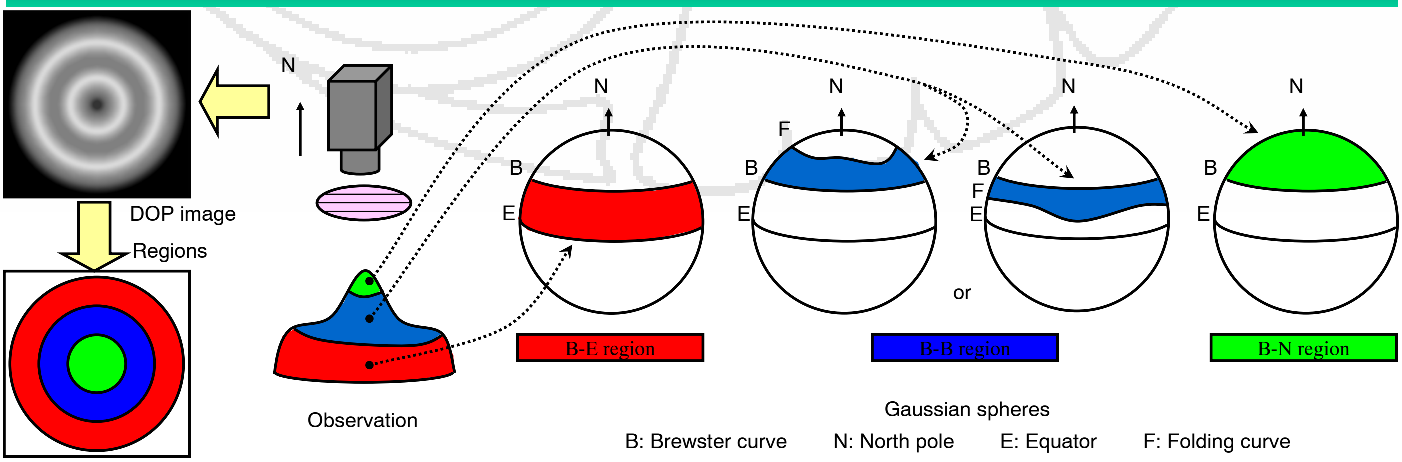
$$\rho' = \frac{2\sin\theta(n^2 - \sin^2\theta - n^2\sin^2\theta)(2n^2 - \sin^2\theta - n^2\sin^2\theta)}{\sqrt{n^2 - \sin^2\theta}(n^2 - \sin^2\theta - n^2\sin^2\theta + 2\sin^4\theta)^2}$$

$$\rho(\theta + \Delta\theta) - \rho(\theta) = \rho'(\theta)\Delta\theta$$

DOP after rotation | DOP before rotation | Derivative of DOP | Rotation angle



Gaussian Mapping and Regions

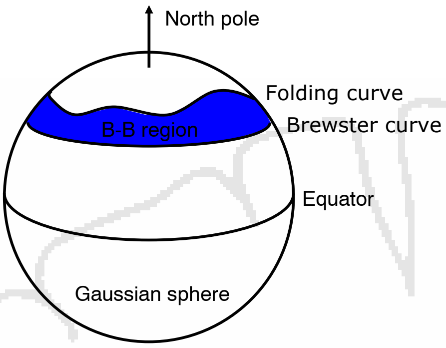


Folding Curve

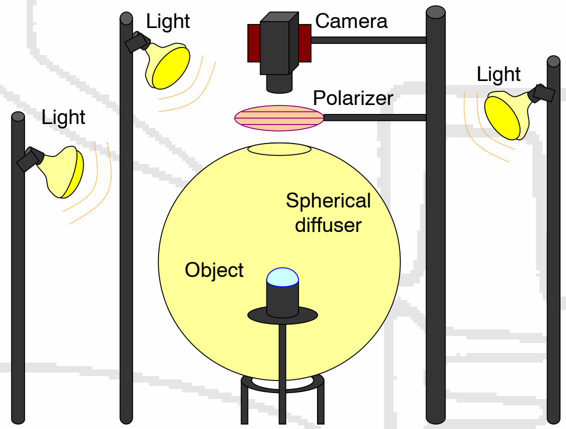
◆**Theorem: Folding curve is parabolic curve**

✧**Parabolic curve = a curve where Gaussian curvature is 0**

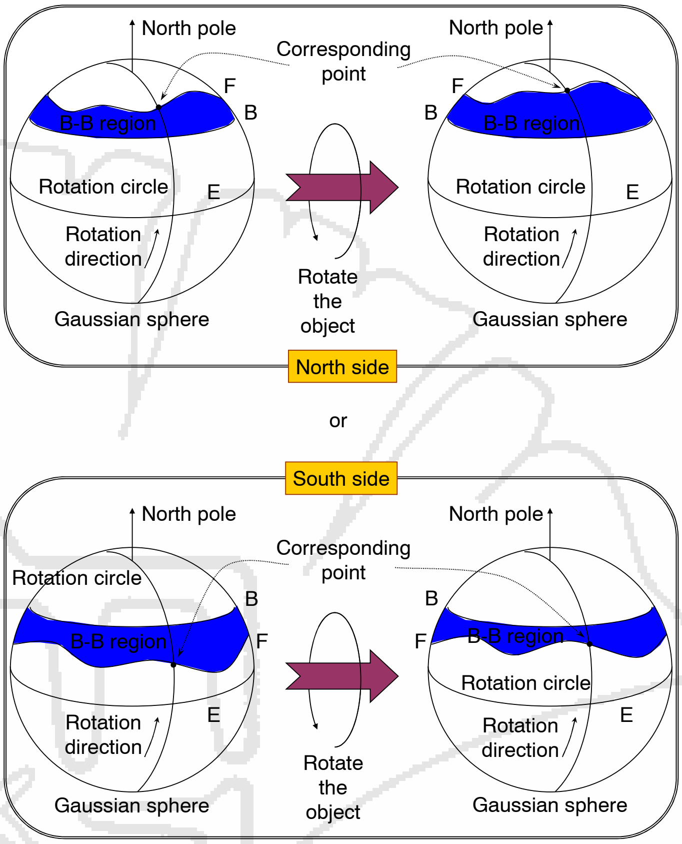
⇒ **Folding curve = geometrical invariant**



Experimental Setup

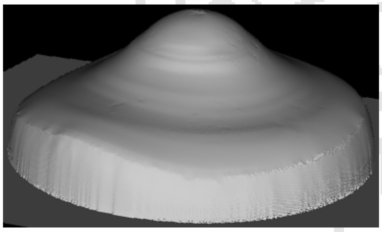


Corresponding Point

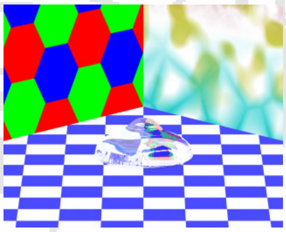


Result for Bell-shaped Transparent Object

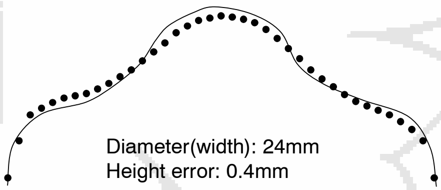
Real Image



Obtained Surface Shape



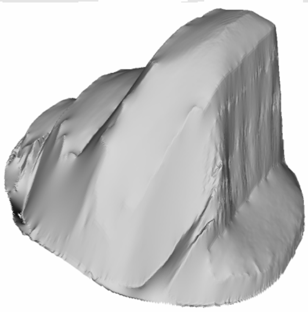
Rendered Image



Solid Line: Ground Truth
Dotted Line: Obtained Shape

Result for Another Object

Real Image



Obtained Surface Shape

Future Work

◆**Improvement of the precision**

✧**by dealing with inter-reflections**

✧**by using multiple data taken under different illuminations**

✧**by using multiple data taken from different views**

◆**Estimation of**

✧**the shape of backward surface**

✧**the refractive index**

✧**the extinction coefficient (=color of translucent objects)**

◆**Real-time system**

◆**Applications to**

✧**entertainments and VR**

✧**modeling cultural assets**

✧**industrial robots for productions such as transparent cellular phones, PCs, toys, etc.**

✧**classifying glass bottles for recycling**