Polarization Imaging

Introduction

Objective

The main goal is to understand how a simple camera can be transformed into a polarization state measurement system. This lab introduces two different systems:

- a simplified polarization imaging set-up that consists of a manually rotating polarizer placed in front of the sensor,
- a contrast polarization measurement system that uses a Twisted Nematic Liquid Crystal.

Equipment

- PC computer
- Frame Grabber - IEEE 1394
- Camera - Allied Vision Technologies GUPPY + one lens + Video Cable
- Arcoptix switchable polarization rotator 0-90° (Twisted Nematic Liquid Crystal) + Arcoptix USB LC Driver
- Two linear polarizers
- Four mounting posts and four post holders
- Lighting Device + Polarized Ring

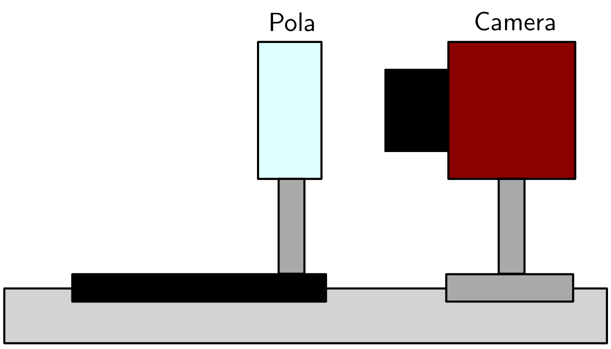
Software

- National Instruments "Measurement & Automation Explorer" Software
- Arcoptix USB LC Software
- Matlab or National Instruments LabVIEW

Simplified polarization imaging

Getting started

1. Design the following imaging set-up:



2. Connect camera cables.
3. Start National Instruments "Measurement & Automation Explorer" software.
4. Select the IEEE1394 Guppy camera.
5. Grab a part of the computer screen and rotate the polarizer to see what happens ▷ give details of what happens ?

Wolff's method

This method is in fact a special case of the Least Mean Square Method...

▷ Before taking images, Settings of the camera like autoexposure and gain must be set to manual: why ?

1. Snap and store 3 images of a scene made of a part of the computer screen with the following polarizer orientations: 0°, 45° and 90°.
2. With Matlab or LabVIEW compute and show the polarization parameters of the scene given by:

$$\begin{cases} I & = I_0 + I_{90} \\ \tan 2\varphi & = \frac{I-2I_{45}}{I-2I_{90}} \\ \rho & = \frac{\sqrt{(I-2I_{45})^2+(I-2I_{90})^2}}{I} \end{cases}$$

   ▷ Describe the images φ and ρ according to the regions of interest.

3. Compute a color image that can represent the three parameters on a single image.

Least Mean Square method

1. Snap and store N ($N = 8$ for instance) images of a scene made of a part of the computer screen with N orientations of the polarizer.

   Questions 2-4 are optional during the lab and can be treated later.

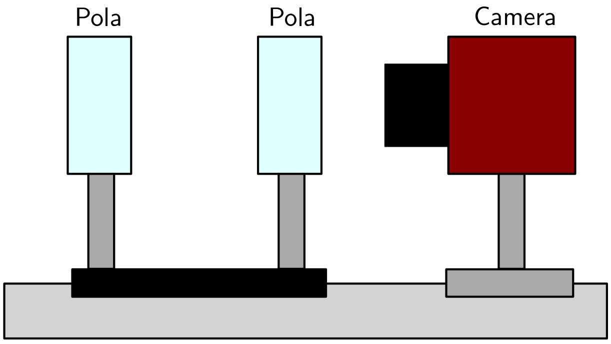
2. Apply the Least Mean Square method to the images to estimate first s_0, s_1 and s_2.
3. Compute and show I, ρ and φ.
4. Draw for some pixels of interest the light intensity measured by the camera according to the angle of the polarizer to show the sinusoidal relationship ▷ detail the results.

Contrast polarization measurement

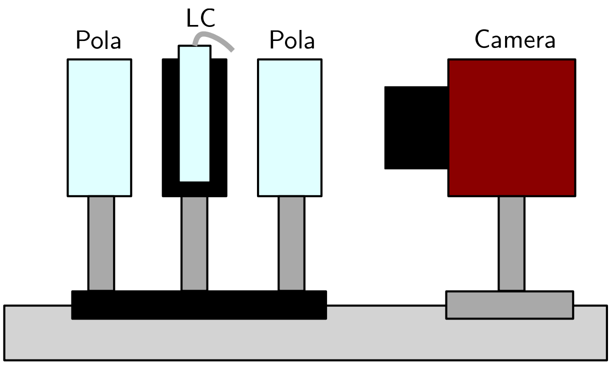
This method consist in taking two different images with two orthogonal directions of a linear polarizer. If an additional polarized lighting according one of these directions is used it enables to estimate the depolarization properties of the object and to remove specular reflections. A liquid crystal rotator is used here to programmaticaly change the orientation of the polarizer.

Getting started

1. Design the following imaging set-up with the two polarizers oriented at 0° and check how light intensity generally decrease (explain why):



2. Mount the Arcoptix switchable polarization rotator 0-90°, insert it between the 2 polarizers:



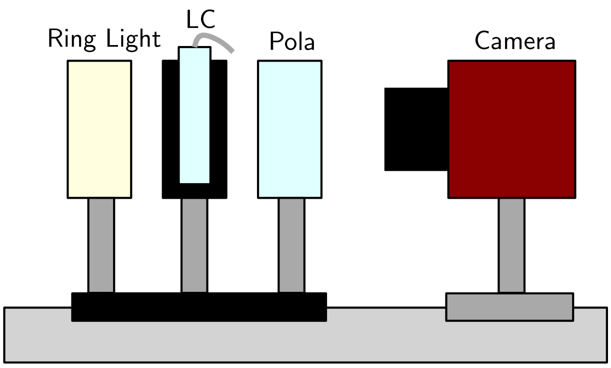
3. Connect Acroptix usb LC Driver to the computer.

4. Grab a scene and play with the Arcoptix software the polarizer to see what happens.

   ▷ explain why ?

Diffuse Specular reflection

1. To remove specular reflections an additional polarized lighting source can be used. Check that the polarizer used in front of the light is parallel to the polarizer in front of the camera:



2. Snap two different images of an object (your hand for instance, but don't move) and store these images $I_{\parallel}$ and $I_{\perp}$.

3. Compute and show the following parameters:

   - Total light intensity: $I_{\parallel} + I_{\perp}$
   - Polarization contrast: $I_{\parallel} - I_{\perp}$
   - Polarization contrast ratio: $\frac{I_{\parallel} - I_{\perp}}{I_{\parallel} + I_{\perp}}$

▷ Show areas containing specular or diffuse reflection.

4. If you have time and know LabVIEW programming, create a program that automatically provides the previous parameters.

End of Lab Course

- Disconnect all Cables.
- Uninstall every optical devices very carefully and store everything as it should be
- Carefully Store every components in the box.

Appendix

Some useful Matlab functions

- `imread` : to read images
- `double` : to return the double precision of an array
- `figure` : to create a figure
- `imagesc` : to show images
- `colormap` : to change the colormap
- `colorbar` : to show the colorbar
- `hsv2rgb` : to create a RGB image from the HSV values