Polarization Imaging Report (Lab 1)

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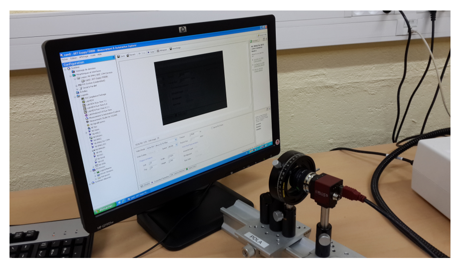
1 Simplified Polarization Imaging

We used the configuration as illustrated on the picture 1 of the instructions:

Because we wanted to see the difference the rotation of the polarizer has on polarized light and unpolarized light, we set up our camera so the computer screen was captured only on one part of the image. We did this because we knew that the light coming from the computer screen is linearly polarized. Moreover, we suspected the orientation polarization is at 45° (as it is on most of the computer screens).

Figure 1



Initially our polarized was oriented at 0°. As we were rotating it clockwise, the intesity on the part of the image showing the screen was increasing until it reached the maximum at 45°. After that, the intensity started to decrease until it was totally blocked at 135°. We also noticed that the intesity at 90° was the same as the intensity at 0°.

This shows that the light coming from the screen was in fact polarized at 45° because when both, angle of polarized light and the polarizer are aligned, a maximum is achieved as none of the light is blocked by the polarizer. In contrast, at 135° the angle between them was orthogonal so everything was blocked and the intesity on the resulting image is 0.

1.1 Wollf's Method

In the camera settings, autoexposure means that the exposure is automatically adjusted according to the ambient light of the scene. Auto Gain Control (AGC) increases the intensifier gain if the video scene is too dim and decreases the gain if the scene is too bright [1].

We can see in the following 2 figures that when autoexposure and AGC are enabled, the camera automatically tries to compensate for brightnes. Since we

Region	Mask Color	I	ϕ	ρ
Border	Green	6.744471	-0.529405	0.441451
Background	Blue	-0.060872	-3.48	0.060838
Screen (filtered)	Red	153.000000	-0.781801	0.908520

Table 1: Obtained results for different Regions of Interest (ROI)

needed to maintain the consistency between the measurements, these parameters were turned off.

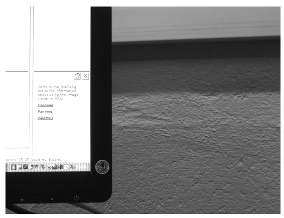


Figure 2: AutoGain On

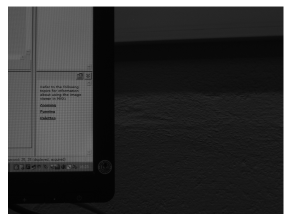


Figure 3: AutoGain Off

Figures 4, 5 and 6 show our images taken at 0°, 45° and 90° respectively. After the capture, we noticed some stripes due to the position of the camera and because of the lower resolution of display in the program we didnt noticed it during the labs. Therefore, the obtained parameters for the intensity, angle of polarization ϕ and degree of polarization ρ were calculated only on the non corrupted pixels for each region of interest shown in figure 7 obtaining the results given by the table 1.

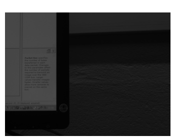


Figure 4: Polarizer at 0°

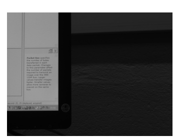


Figure 5: Polarizer at 45°

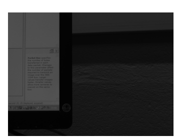


Figure 6: Polarizer at 90°

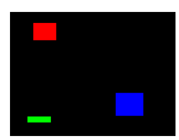
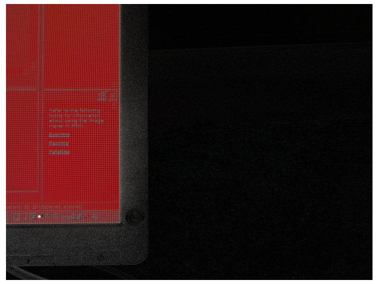


Figure 7: Regions of Interest (Mask)

In order to display the polarization parameteres we used the HSL representation by performing the following mapping: $H \to 2\phi$, $S \to I$ and $L \to \rho$ as in the slides. The result is shown in figure 8.

Figure 8: HSL representation of Polarization



1.2 Least Mean Square Method

In this section we took 10 different measurements with different rotations of the polarizer as shown in the figures 9 to 18 in order to get a better approximation of the polarization parameters.

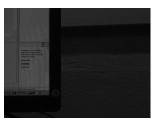


Figure 9: 0°

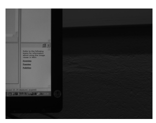


Figure 10: 20°

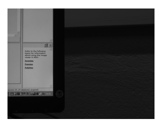


Figure 11: 40°

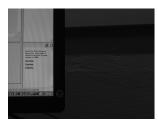


Figure 12: 60°

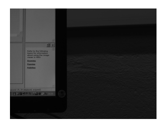


Figure 13: 80°

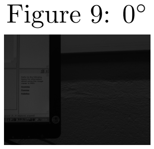


Figure 14: 100°

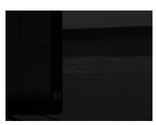


Figure 15: 120°

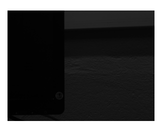


Figure 16: 140°

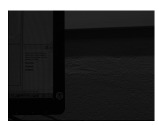


Figure 17: 160°

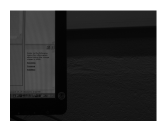


Figure 18: 180°

The obtained image after calculating the LMS with the 10 images is shown in the figure 19. For the analyzed pixels in the screen we obtained a sinusoidal relation as can be seen in the figure 20. This results are consecuent with the Malus Law $I = I_0 cos^2 \alpha$ in which the maximum intesity is obtained when the angle α of the polarizer matches the polarized light (at around 45°) and none intensity where they are orthogonal (around 135°)..

Figure 19: HSL representation of LMS results

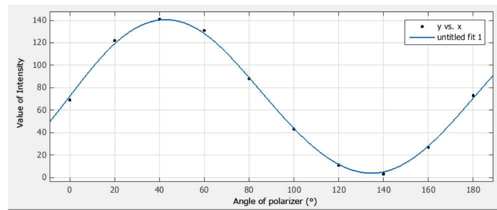


Figure 20: Sinusoidal Wave of Single Pixel

2 Contrast Polarization Measurement

The first thing we noticed was the difference of the obtained intensity of the image when we used only one polarizer at 0° (figure 21) versus the one obtained with 2 polarizers (figure 22) also at 0°. The expeced result when two ideal polarizers are oriented with the same angle would be to obtain the whole intensity from one to another. However, this is not true in practice because in general they absorb or reflect some part of the optical power [2]. This means the obtained intensity will be given by the transmission coefficient of each of the polarizers.

Also, figure 23 shows the result when both polarizers were oriented orthogonally. In this case we could see a total blocking of the light as expected.

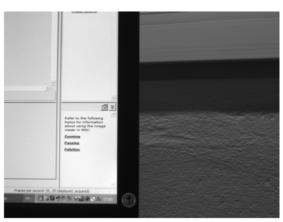


Figure 21: Image after 1st polarizer

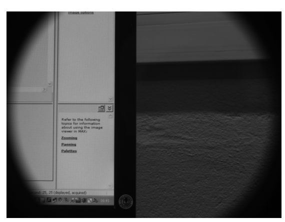


Figure 22: Image after both polarizers at 0

Figure 23: Image after both polarizers at 90

The next step was to introduce the TNLC rotator to see its effect. We know that this device should act as a "switch" for the polarization rotation: one state when no voltage is applied and the other when the maximum voltage is applied. However, we didn't know the angle of rotation in either of the states.

For this, we placed the TNLC in the middle and take 2 measurements: first with 0v and another with a maximum voltage (see figures 24 and 25).

We observed that when no voltage was applied, we got a black image. We could infere then that at 0V the TNLC was orthogonally oriented with respect of the polarizers, which means it was oriented at 90°. Similarly, when we applied the maximum voltage, we got the maximum intensity and therefore we can deduce it was aligned with the other two polarizers at 0°.

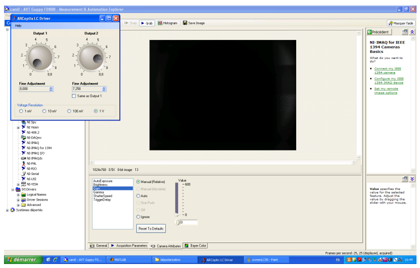


Figure 24: TNLC at 0V

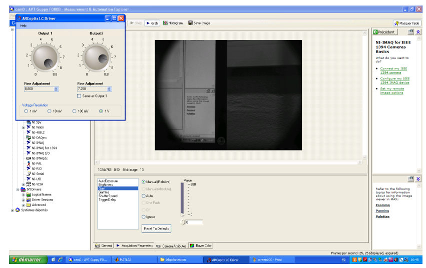


Figure 25: TNLC at Max V

3 Difuse Specular Reflection

The idea of this section was to make use of the effect of specular and difuse reflection over linearly polarized light. We knew that difuse reflection causes that the incident linearly polarized light becomes unpolarized and that specular reflection preserves the polarization. That is why, in order to get rid of the specular reflection, we only needed to cancel it out by rotating the polarized light 90° with respect to the polarizer. This was achieved by using the TNLC.

First, we aligned the polarizer used in front of the light with the polarizer in front of the camera. This means that the generated linearly polarized light was paralel to the polarizer .

The first picture was taken by applying the maximum voltage to the TNLC so that no rotation was performed on the incident linearly polarized light. This meant that both, incident polarized light and polarizer were parallel (figure 26 left).

For the second picture, no voltage was applied on the TNLC, and therefore a 90° was performed on the linearly polarized light (figure 26 right), therefore the specular reflection was cancelled.

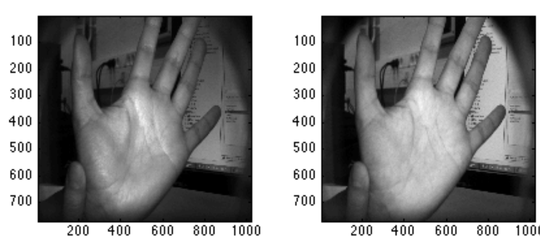


Figure 26: Image 1 Rotator at

The calculated parameters for total light intensity, polarization contrast and polarization contrast ratio are shown in the figure 27. All the images were shown by scaling the obtained intensity except for the bottom right one. We wanted to enhance the polarized areas in the polarization contrast image by just discarding the negative values and then negating the image. Here we could clearly visualize that the black portion of the picture corresponds to the specular reflection.

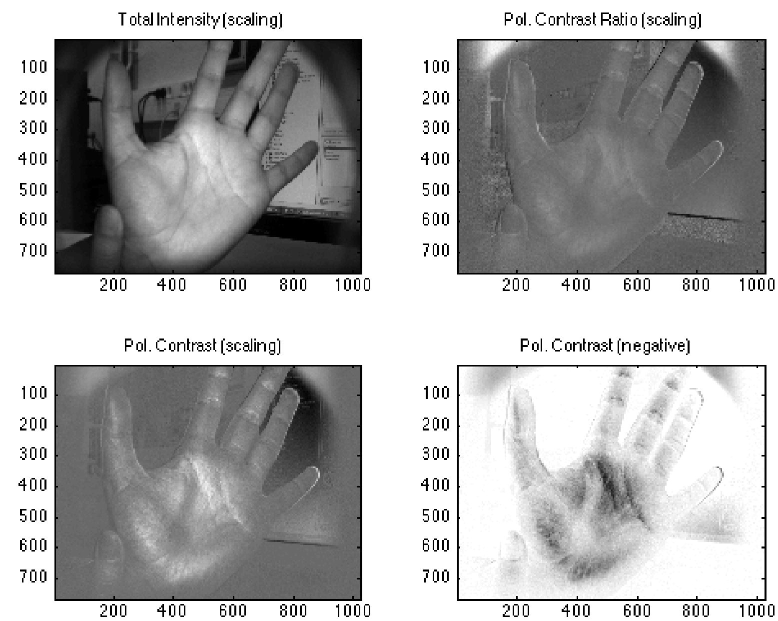


Figure 27: Image 1 filtered (without specular reflection)

References

[1] Kim R Fowler. Automatic gain control for image-intensified camera. *Instrumentation and Measurement, IEEE Transactions on*, 53(4):1057–1064, 2004.

[2] Rdiger Paschotta. Rp photonics encyclopedia. `http://www.rp-photonics.com/polarizers.html`, November 2013.