can lead to serious errors if the measurements I_0, I_{45}, I_{90} are small. We observe that any two triplets, $t_i = (I_0^i, I_{45}^i, I_{90}^i)$ and $t_j = (I_0^j, I_{45}^j, I_{90}^j)$, leading to the same α, P values are proportional, i.e. $t_i = kt_j$. Consider k in the range [0.005,1], so that when $k = 1$, at least one of the triplets' component is 255. With such choices, k can be interpreted as an *intensity attenuation factor*; the smaller k, the fainter the intensities in the triplet leading to a given polarization state α, P. Figures 3(a) ands 3(b) show that the actual error caused by quantisation on the α estimates increases significantly when the intensity is attenuated. The graphs were obtained by plotting E_α (Eq.(15)) with $E_n = 0$. Notice that the predicted angular errors can exceed 45° even in the absence of any other noise. This analysis gives important suggestions on equipment characteristics; for instance, with 8-bit images, the dynamic range guaranteeing maximum absolute errors within 5° is only 10 to 20 (1/0.1 to 1/0.05); 10-bit images could be used to achieve better ranges for practical purposes.

6 Conclusion

Polarization-based vision provides important clues for the interpretation of a scene, but at the cost of more demanding requirements for the vision system. Since all measurements, including those for calibrating optic elements, come ultimately from the imaging system, it is important to have guidelines for correct equipment settings, and to analyse the causes and effects of error sources on the target measurements. Here, we have considered the most common architecture of polarization vision systems, and concentrated on an important parameter estimated in many polarization-based tasks, the orientation of the polarized component of the observed light. Our analysis predicts the maximum error on orientation estimates as a function of the quantised intensity values and video channel noise, thus making it possible to choose adequate experimental parameters, and to discard intensity measurements leading to unacceptably high errors.

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Appendix

This Appendix sketches the derivation of Eq.(15). Assuming digitized intensity measurements are I_0, I_{45}, I_{90}, the original measurement errors are E_0, E_{45}, E_{90} respectively. The actual intensity is given by:

$$\left.\begin{array}{rcl} I_0^{'} & = & I_0 + E_0 \\ I_{45}^{'} & = & I_{45} + E_{45} \\ I_{90}^{'} & = & I_{90} + E_{90} \end{array}\right\} \tag{A.1}$$

where E_0, E_{45}, E_{90} can take either positive or negative values. The measurement orientation α and the actual orientation $\alpha + E_\alpha$ are:

$$tan\,2\alpha = \frac{2I_{45} - I_0 - I_{90}}{I_0 - I_{90}} \tag{A.2}$$

$$tan\,2(\alpha + E_\alpha) = \frac{2\,(I_{45} + E_{45}) - (I_0 + E_0) - (I_{90} + E_{90})}{(I_0 + E_0) - (I_{90} + E_{90})} \tag{A.3}$$

Let

$$A = tan\,2(\alpha + E_\alpha) - tan\,2(\alpha) \tag{A.4}$$

then, expanding $tan2(\alpha + E_\alpha)$,

$$tan\,2E_\alpha = \frac{A}{tan^2 2\alpha + A\,tan\,2\alpha + 1} \tag{A.5}$$

From Eq.(A.2) to Eq.(A.5), we have:

$$tan\,2E_\alpha = \frac{(I_{90} - I_{45})\,E_0 - (I_{90} - I_0)\,E_{45} - (I_0 - I_{45})\,E_{90}}{(I_0 - I_{45})^2 + (I_{90} - I_{45})^2 + (I_0 - I_{45})E_0 - (I_0 + I_{90} - 2\,I_{45})E_{45} + (I_{90} - I_{45})E_{90}} \tag{A.6}$$