Polarized Optical-Flow Gyroscope: Supplementary Material

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Abstract. This is a supplementary document to the main manuscript. Here we provide a demonstration of angular-velocity estimation from a polarized single-pixel sensor. We also display the polarization and intensity properties of the simulated and experimental scenes.

1 Single-Pixel Sensor

Consider a camera with a wide field of view, but no spatial resolution (a single pixel). A constant rotation rate may be estimated by fitting the change in the single-pixel intensity. Recall Eq. (2) of the main manuscript:

$$I(\boldsymbol{x}_{\text{cam}}) = I(\mathcal{T}\boldsymbol{x}_{\text{obj}}) = \frac{c(\boldsymbol{x}_{\text{obj}})}{2}\left\{1 + p(\boldsymbol{x}_{\text{obj}})\cos 2\left[\alpha - \theta(\boldsymbol{x}_{\text{obj}})\right]\right\}. \tag{1}$$

Prior to rotation, the polarizer axis is α_0. Then $\alpha = \alpha_0 + \omega t$. Eq. (1) above becomes

$$I_{\text{cam}} = \frac{c_{\text{obj}}}{2}\left\{1 + p_{\text{obj}}\cos 2\left[\omega t - \tilde{\theta}_{\text{obj}}\right]\right\}, \tag{2}$$

where $\tilde{\theta}_{\text{obj}} = \theta_{\text{obj}} - \alpha_0$. This problem has four unknowns: c_{obj}, p_{obj}, $\tilde{\theta}_{\text{obj}}$, and the angular velocity ω. Therefore, under constant rate of rotation, a solution requires four measurements at different known time instances.

We demonstrate this principle using the experimental images. In lieu of a single wide field pixel, we used the spatial mean intensity of an image. The spatial mean intensity in a sequence of of images can be fitted by Least Square (LS) to Eq. (2) above.

$$\{\hat{c}_{\text{obj}}, \hat{p}_{\text{obj}}, \hat{\theta}_{\text{obj}}, \hat{\omega}\} = \underset{c_{\text{obj}}, p_{\text{obj}}, \tilde{\theta}_{\text{obj}}, \omega}{\operatorname{argmin}} \sum_{t=1}^{K} \left| I_{\text{cam}}(t) - \frac{c_{\text{obj}}}{2}\left\{1 + p_{\text{obj}}\cos 2\left[\omega t - \tilde{\theta}_{\text{obj}}\right]\right\}\right|^2, \tag{3}$$

where $K \geq 4$ is the number of frames. In our case, fitting was done via the MatLab *cftool* curve fitting tool. The true and estimated values of ω are presented in Table 1. Scenes with strong, homogeneous polarization, e.g. *LCD screen* and *Sky*, had more successful estimations.

Table 1. The true values of ω, and values estimated from LS fitting to Eq. (2)

Scene	*LCD screen*	*Kitchen*	*Sky*	*Elevator*
True ω [deg/frame]	10	6	10	6
estimated ω [deg/frame]	10.18	8.5	7.8	8.6

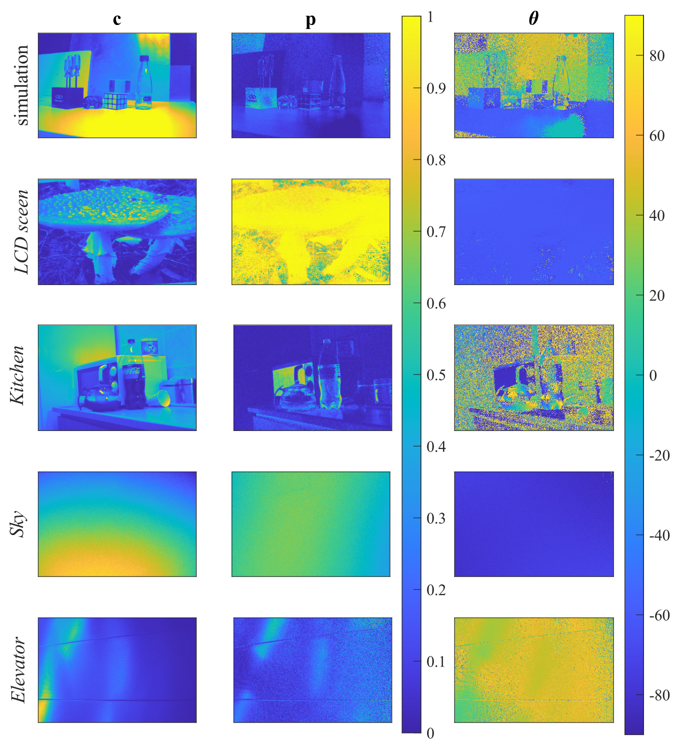

Fig. 1. Polarization and intensity properties of simulated and experimental scenes.

2 Polarization Properties

Fig. 1 presents the ground-truth intensity c, degree of polarization p, and angle of polarization θ, of all simulated and experimental scenes.