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► **To cite this version:**

Léo Poughon, Vincent Aubry, Jocelyn Monnoyer, Stéphane Viollet, Julien Serres. Skylight polarization heading sensor using waveplate retardance shift with incidence. Journée des Jeunes Chercheurs en Robotique (JJCR 2023), GDR Robotique; Franck Ruffier; Maan El Badaoui El Najjar, Oct 2023, Moliets et Maâ, France. hal-04521170

**HAL Id: hal-04521170**

**<https://hal.science/hal-04521170>**

Submitted on 26 Mar 2024

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# Skylight polarization heading sensor using waveplate retardance shift with incidence

Léo Poughon<sup>1,2</sup>, Vincent Aubry<sup>2</sup>, Jocelyn Monnoyer<sup>2</sup>,

Stéphane Viollet<sup>1</sup>, Julien R Serres<sup>1,3</sup>

<sup>1</sup>*Aix Marseille Univ, CNRS, ISM, 163 Av. de Luminy, 13 009 Marseille, France*

<sup>2</sup>*Stellantis, Rte de Gisy, 78 140 Velizy-Villacoublay, France*

<sup>3</sup>*Institut Universitaire de France (IUF), 1 rue Descartes, 72 231 Paris cedex 05, France*

**Keywords:** Skylight Polarization, Navigation, Deep Learning, Heading, Celestial Compass, Polarized Vision.

In nature, navigating insects such as ants, bees and flies rely on the polarization of light scattered by the sky to estimate their orientation relative to the sun, and thus orient themselves [1]. Numerous artificial sensors have been proposed in an attempt to reproduce their optical compass [2, 3, 4] but none is yet fully satisfactory for automotive use, either in terms of robustness, size, acquisition time or cost ( $\sim\text{€}2,500$  for a polarimetric camera).

This study describes a innovative heading sensor architecture based on polarization pattern detection via an optical transformation (patent application [5]). This architecture is based on variations in the retardance of a waveplate as a function of the angle of incidence of the polarized light rays, resulting in the appearance on the image of iridescent colors, depending on the orientation of the incident rays and the state of polarization. The outcome is a low-cost, lightweight sensor that would cost about the same the color camera used (here a Raspberry Pi color camera, i.e.  $\sim\text{€}30$ ).

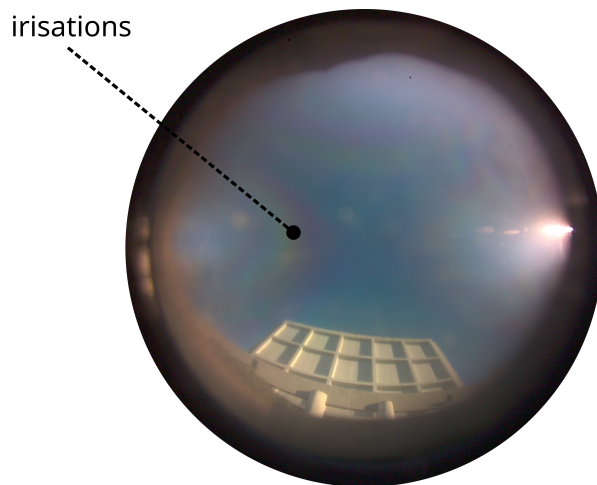


Figure 1: Outdoor image obtained by clear sky, in front of a building. Iridescent colors can be seen.

An optical simulation of the light-sensor interaction is presented, including a complete acquisition chain simulation (Rayleigh sky model, waveplate model in regard of incidence of rays, lens distortion, and color sensor).

A prototype based on the use of a plastic waveplate was built and fixated on a rotating motorized mount, allowing us to get outdoor images of sky with known sensor orientation regarding to the sun (Fig. 2).

Finally, methods for processing this type of images (Fig. 1) to estimate heading based on a convolutional neural network training with will also be discussed.



Figure 2: Motorized rotative mount supporting the optical sensor during outdoor experiments.

## References

- [1] Gábor Horváth and Dezső Varjú. *Polarized Light in Animal Vision*. Springer Berlin Heidelberg, Berlin, Heidelberg, 2004.
- [2] Salmah Karman, S. Diah, and Ille Gebeshuber. Bio-Inspired Polarized Skylight-Based Navigation Sensors: A Review. *Sensors*, 12(11):14232–14261, October 2012.
- [3] Julien Dupeyroux, Julien R. Serres, and Stéphane Viollet. AntBot: A six-legged walking robot able to home like desert ants in outdoor environments. *Science Robotics*, 4(27):eaau0307, February 2019.
- [4] Fang Kong, Yingjing Guo, Jianhua Zhang, Xiaojing Fan, and Xiaohan Guo. Review on bio-inspired polarized skylight navigation. *Chinese Journal of Aeronautics*, 36(9):14–37, 2023.
- [5] Léo Poughon, Stefano Mafrika, Jocelyn Monnoyer, Laetitia Pradere, Julien R Serres, and Stéphane Viollet. Procédé et système pour déterminer des données caractérisant un cap suivi par un véhicule automobile à un instant courant. (FR3128528A1), 2021.