Providing an autonomous hexapod walking robot with the ability to reorientate: application of a novel ant-inspired celestial compass

Julien Dupeyroux, Stéphane Viollet, Julien Serres

Providing an autonomous hexapod walking robot with the ability to reorientate: application of a novel ant-inspired celestial compass

Julien Dupeyroux, Stéphane Viollet and Julien Serres
Aix Marseille Univ, CNRS, ISM, Marseille, France.

***Abstract*— Insects like desert ants have photoreceptors in their Dorsal Rim Area sensitive to the ultraviolet skylight polarization pattern. Taking inspiration from insects allows us to develop smart sensors. A bio-inspired celestial compass has been developed in the aim of stabilizing the heading of a hexapod robot, which can estimate its heading direction from the linearly polarized skylight in the ultraviolet (UV) range. Field results will be presented and will show their reliability and accuracy with respect to various weather conditions. Finally, our celestial compass can be used as an alternative to both magnetometers failure in highly disturbed environment, and GPS limited precision.**

I. INTRODUCTION

The classical methods to provide the heading direction of mobile robots mainly rely on the use of inertial measurement units (IMUs) and global positionning systems (GPS). Unfortunately, IMUs remain highly sensitive to any electromagnetic disruptions produced by ferrous materials. In addition, GPS-based solutions only provide metric precision which does not fit small scale mobile robotics tasks.

The study of the insects' navigational toolkit showed that many of them such as desert ants, bees, and locusts make use of the skylight polarization as a visual cue to estimate their heading direction [1], mostly in the UV-range. The sunlight is indeed linearly polarized when crossing the Earth's atmosphere [2]. The angle of polarization keeps stable over short-term so that insects can rely on that information to complete their navigation tasks like homing.

II. THE CELESTIAL COMPASS

A new insect inspired celestial compass has been developed and embedded onto a six-legged walking robot ([3], [4], [5]) (fig. 1). This sensor is made of two UV-light sensors (SG01D18, SgLux) topped with rotating UV linear sheet polarizers (HNP'B replacement). The angular directions of the polarizers are phase-shiffted by 90°. The full prototype is 3D-printed with polyactic acid (PLA) filament.

According to both scanning and simultaneous models introduced by Lambrinos et al. [6], we propose to merge these models into one, so that the measurement of the polarization direction is performed by rotating the polarizers by 360° at fixed angular resolution (up to 0.64°). The signals measured by the two units are cosine waves with 180° phase shift. The log-ratio of the two signals is then computed, where the polarization direction corresponds to the angle with the minimum log-ratio value.

Outdoor tests under various weather conditions (clear, variable and overcast sky) were performed to describe qualitatively and quantitatively the ability of the sensor to provide reliable heading direction to the robot during heading lock navigational tasks. Tests were conducted during winter (February 2017) with a very low UV-index (up to 2). The results were highly precise and reliable under clear-sky conditions, with an average heading steady state error as small as 0.4°. Results under cloudy-sky conditions exhibits good performances as well, from 0.8° under variable weather, to 1.9° under overcast sky, but slightly less reliable due to the high variability of meteorological conditions.

Fig. 1. Top view of the Hexabot robot equipped with the UV-polarized light compass.

REFERENCES

[1] R. Wehner, B. Michel, and P. Antonsen, Visual navigation in insects: coupling of egocentric and geocentric information, Journal of Experimental Biology, vol. 199, pp. 129-140, 1996.

[2] K.L. Coulson, Polarization and Intensity of Light in the Atmosphere, A Deepak Pub, 1988.

[3] J. Dupeyroux, J. Diperi, M. Boyron, S. Viollet, and J. Serres, A novel insect-inspired optical compass sensor for a hexapod walking robot, Intelligent Robots and Systems (IROS), 2017 IEEE/RSJ International Conference on, in press, 2017.

[4] J. Dupeyroux, J. Diperi, M. Boyron, S. Viollet, and J. Serres, A novel insect-inspired optical compass sensor for a hexapod walking robot, A bio-inspired celestial compass applied to an ant-inspired robot for autonomous navigation. European Conference on Mobile Robotics (ECMR), in press, 2017.

[5] J. Dupeyroux, G. Passault, F. Ruffier, S. Viollet, and J. Serres, Hexabot: a small 3D-printed six-legged walking robot designed for desert ant-like navigation tasks, 20th World Congress of the International Federation of Automatic Control (IFAC), Toulouse, France, pp. 16628-16631, 2017.

[6] D. Lambrinos, H. Kobayashi, R. Pfeifer, M. Maris, T. Labhart and R. Wehner, An autonomous agent navigating with a polarized light compass, Adaptive Behavior, vol. 6, pp. 131-161, 1997.