Polarization-based Robot Orientation and Navigation: Progress and Insights

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ABSTRACT

From insects in your garden to creatures in the sea, inspiration can be drawn from nature to design a whole new class of smart robotic devices. These smart machines may move like living creatures. They can be launched toward a specific target for a pre-defined task. Bio-inspiration is developing to meet the needs of many challenges particularly in machine vision. Some species in the animal kingdom like cephalopods, crustaceans and insects are distinguished with their visual capabilities which are strongly improved by means of polarization. This work surveys the most recent research in the area of bio-inspired polarization based robot orientation and navigation. Firstly, the authors will briefly discuss the polarization based orientation and navigation behavior in the animal kingdom. Secondly, a comprehensive cover of its mapping into robotics navigation and orientation estimation will be given. Finally, the future research directions will be discussed.

Keywords: Attitude Estimation, Bio-Inspiration, Hazards Detection, Navigation, Orientation, Polarization, Robotics, Skylight Patterns

INTRODUCTION

Sky polarization patterns are used by many insects for navigation. Honeybees use celestial polarization to move between the hive and foraging locations (Cronin et al., 2003; Horváth, 2014). Cataglyphis ants (Cronin et al., 2003) and Dung beetles (Dacke, Byrne, Baird, Scholtz, & Warrant, 2011) use the sun and moon, respectively, celestial polarization for similar tasks. At present, Dung beetles maintain travel direction by means of polarization where they are the only animal group known to use the much dimmer polarization pattern shaped around the Moon as a compass cue for orientation (Dacke et al., 2011). See Figure 1.

Salmon fishes (Figure 1) may have a similar ability (Hawryshyn, 1992), which allows them to orient in underwater light fields (Novales & Hawryshyn, 1997). Light reflection from water

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surfaces results in horizontally polarized light which is utilized by water beetles and other insects for orientation. (Schwind, 1991).

Many researchers have made theoretical and experimental investigations on skylight polarization for autonomous orientation and navigation. The sky is polarized due to the scattering of sunlight by particles and air molecules in the atmosphere. The sky polarization patterns present us with the polarization information which can be used as an external compass.

This work surveys the different bio-inspired polarization techniques for robot orientation and navigation. It is a focused discussion of orientation and navigation techniques of (Shabayek, Morel, & Fofi 2013; Shabayek, Morel, & Fofi 2015) where the most recent research in the area of bio-inspired polarization based techniques is covered. The methods are classified according to the type of visual sensors used for orientation and navigation as Photodiodes, CCD/CMOS, and special sensors.

The main contribution of this work is the comprehensive and novel view of polarization based robots orientation and navigation. The techniques are classified according to the used sensor technology. In the light of visual sensors technology, the future research directions in robotics navigation based on polarization will be discussed.
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