Chapter 72

Visual Behavior Based Bio–Inspired Polarization Techniques in Computer Vision and Robotics

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ABSTRACT

For long time, it was thought that the sensing of polarization by animals is invariably related to their behavior, such as navigation and orientation. Recently, it was found that polarization can be part of a high-level visual perception, permitting a wide area of vision applications. Polarization vision can be used for most tasks of color vision including object recognition, contrast enhancement, camouflage breaking, and signal detection and discrimination. The polarization based visual behavior found in the animal kingdom is briefly covered. Then, the authors go in depth with the bio-inspired applications based on polarization in computer vision and robotics. The aim is to have a comprehensive survey highlighting the key principles of polarization based techniques and how they are biologically inspired.

INTRODUCTION

Bio-inspiration is an established concept which is developing to meet the needs of many applications, particularly in machine vision. Polarization vision is one of the most important biological

features in the animal kingdom. A broad range of applications has been inspired by it. What is polarization? Polarization is the phenomenon that describes the oscillations of orientation in light (or other radiation) waves which are restricted in direction (Goldstein, 2003). Light's vector orientation can be surprisingly weakly detected by some humans with their naked eyes (Haidinger, 1844),

but humans need the help of polarizing optics to visualize most invisible polarization effects (Green, Ohmann, Leininger, & Kavanaugh, 2010).

Many fish, cephalopods, crustaceans, insects, and other animals are capable of perceiving polarized light (Horváth & Varjú, 2004). Most animal photoreceptors are able to differentially react to partially linearly polarized light (Goldsmith, 1975; Nilsson & Warrant, 1999; Waterman, 1981; Wehner, 2001). The photoreceptors of ish (Hawryshyn, 1992) and birds (Phillips & Wald-vogel, 1988) respond to polarized light patterns and hence are able to analyze linear polarization (Cronin et al., 2003).

Firstly, we will briefly cover the polarization based visual behavior in the animal kingdom, especially behaviors that can be mapped directly to the machine vision world such as orientation and navigation, water and transparent object detection, camouflage breaking, and communication. Secondly, a comprehensive review of polarization-inspired machine vision applications will be given. Finally, future research directions in bio-inspired machine vision applications based on polarization will be discussed.

The main part of the chapter will go into details regarding bio-inspired polarization techniques in robotics applications. We start with a short survey of how to visualize polarization information. Then a detailed complete survey of robot orientation and navigation techniques based on polarization will be given due to their importance to computer vision and robotics communities and ongoing research. A comprehensive survey of underwater polarization vision is also given due to the challenging problem of enhancing vision underwater and how it is greatly improved using polarization. A moderate survey of communication (few methods are clearly bio-inspired) and camouflage breaking techniques based on polarization are then covered. Finally, examples of general computer vision techniques based on polarization are mentioned.

Our objective is to give a overview of polarization applications in computer vision and robotics, especially the bio-inspired polarization dependent techniques in order to have comprehensive coverage of such an important and active area of research.

POLARIZATION BASED VISUAL BEHAVIOR IN THE ANIMAL KINGDOM

Orientation and Navigation

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; Rossel,1989; Wehner, 2001). Cataglyphis ants (Cronin et al., 2003) and nocturnal ball-rolling dung beetle (Dacke, Byrne, Baird, Scholtz, & Warrant, 2011) use the sun and moon, respectively, celestial polarization for similar tasks. 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 surfaces results in horizontally polarized light which is utilized by water beetles and other insects for orientation. (Schwind, 1983; Schwind, 1984; Schwind, 1991).

Figure 1. Polarization in the animal kingdom

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