

HOPS: A Hybrid Dual Camera Vision System

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INTRODUCTION

Biological vision processes are usually characterized by the following different phases:

- Awareness: natural or artificial agents operating in dynamic environments can benefit from a, possibly rough, global description of the surroundings. In human this is referred to as peripheral vision, since it derives from stimuli coming from the edge of the retina.
- Attention: once an interesting object/event has been detected, higher resolution is required to set focus on it and plan an appropriate reaction. In human this corresponds to the so-called foveal vision, since it originates from the center of the retina (fovea).
- Analysis: extraction of detailed information about objects of interest, their three-dimensional structure and their spatial relationships completes the vision process. Achievement of these goals requires at least two views of the surrounding scene with known geometrical relations. In humans, this function is performed exploiting binocular (stereo) vision.

Computer Vision has often tried to emulate natural systems or, at least, to take inspiration from them. In fact, different levels of resolution are useful also in machine vision. In the last decade a number of studies dealing with multiple cameras at different resolutions have appeared in literature. Furthermore, the ever-growing computer performances and the ever-decreasing cost of video equipment make it possible to develop systems

which rely mostly, or even exclusively, on vision for navigating and reacting to environmental changes in real time. Moreover, using vision as the unique sensory input makes artificial perception closer to human perception, unlike systems relying on other kinds of sensors and allows for the development of more direct biologically-inspired approaches to interaction with the external environment (Trullier 1997).

This article presents HOPS (Hybrid Omnidirectional Pin-hole Sensor), a class of dual camera vision sensors that try to exalt the connection between machine vision and biological vision.

BACKGROUND

In the last decade some investigations on hybrid dual camera systems have been performed (Nayar 1997; Cui 1998; Adorni 2001; Adorni 2002; Adorni 2003; Scotti 2005; Yao 2006). The joint use of a moving standard camera and of a catadioptric sensor provides these sensors with their different and complementary features: while the traditional camera can be used to acquire detailed information about a limited region of interest ("foveal vision"), the omnidirectional sensor provides wide-range, but less detailed, information about the surroundings ("peripheral vision"). Possible employments for this class of vision systems are video surveillance applications as well as mobile robot navigation tasks. Moreover, their particular configuration makes it possible to realize different strategies to control the orientation of the standard camera; for example, scattered focus on different objects permits to perform recognition/classification tasks while continu-

ous movements allow to track any interesting moving object. Three-dimensional reconstruction based on stereo vision is also possible.

HOPS: HYBRID OMNIDIRECTIONAL PIN-HOLE SENSOR

This article is focused on the latest prototype of the HOPS (Hybrid Omnidirectional-Pinhole Sensor) sensor (Adorni 2001; Adorni 2002; Adorni 2003, Cagnoni 2007). HOPS is a dual camera vision system that achieves a high-resolution 360-degrees field of view as well as 3D reconstruction capabilities. The effectiveness of this hybrid sensor derives from the joint use of a traditional camera and a central catadioptric camera which both satisfy the single-viewpoint constraint. Having two different viewpoints from which the world is observed, the sensor can therefore act as a stereo pair finding effective applications in surveillance and robot navigation.

To create a handy versatile system that could meet the requirements of the whole vision process in a wide variety of applications, HOPS has been designed to be considered as a single integrated object: one of the most direct advantages offered by this is that, once it is

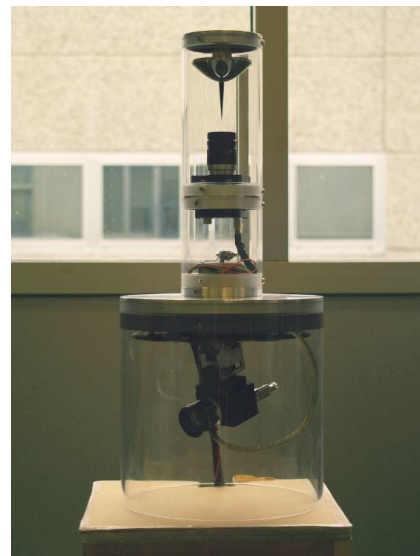
assembled and calibrated, it can be placed and moved anywhere (for example in the middle of a room ceiling or on a mobile robot) without any need for further calibrations.

Figure 1 shows the latest two HOPS prototypes. In the one that has been used for the experiments reported here, the traditional camera which, in this version, cannot rotate, has been placed on top and can be pointed downwards with an appropriate fixed tilt angle to obtain a high-resolution view of a restricted region close to the sensor. In the middle, one can see the catadioptric camera consisting of a traditional camera pointing upwards to a hyperbolic mirror hanging over it and held by a plexiglas cylinder. As can be observed, the mirror can be moved up and down to permit optimal positioning (Swaminathan 2001; Strelow 2001) during calibration.

Moreover, to avoid undesired light reflections on the internal surface of the Plexiglas cylinder, a black needle has been placed on the mirror apex as suggested in (Ishiguro 2001). Finally, in the lower part, some circuits generate video synchronization signals and allow for external connections.

The newer version of HOPS (see Figure 1, right) overcomes some limitations of the present one. It uses two digital high-resolution Firewire cameras,

Figure 1. The two latest versions of the HOPS sensor: the one used for experiments (left) and the newest version (right) which is currently being assembled and tested.



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