

Hybrid Dual Camera Vision Systems

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INTRODUCTION

Many of the known visual systems in nature are characterized by a wide field of view allowing animals to keep the whole surrounding environment under control. In this sense, dragonflies are one of the best examples: their compound eyes are made up of thousands of separate light-sensing organs arranged to give nearly a 360° field of vision. However, animals with eyes on the sides of their head have high periscopy but low binocularity, that is their views overlap very little. Differently, raptors' eyes have a central part that permits them to see far away details with an impressive resolution and their views overlap by about ninety degrees. Those characteristics allow for a globally wide field of view and for accurate stereoscopic vision at the same time, which in turn allows for determination of distance, leading to the ability to develop a sharp, three-dimensional image of a large portion of their view.

In mobile robotics applications, autonomous robots are required to react to visual stimuli that may come from any direction at any moment of their activity. In surveillance applications, the opportunity to obtain a field of view as wide as possible is also a critical requirement. For these reasons, a growing interest in omnidirectional vision systems (Benosman 2001), which is still a particularly intriguing research field, has emerged. On the other hand, requirements to be able to carry out object/pattern recognition and classification tasks are opposite, high resolution and accuracy and low distortion being possibly the most important ones. Finally, three-dimensional information extraction can be usually achieved by vision systems that combine the use of at least two sensors at the same time.

This article presents the class of hybrid dual camera vision systems. This kind of sensors, inspired by existing visual systems in nature, combines an omnidirectional sensor with a perspective moving camera. In this way it is possible to observe the whole surrounding scene at low resolution, while, at the same time, the perspective camera can be directed to focus on objects of interest with higher resolution.

BACKGROUND

There are essentially two ways to observe a very wide area. It is possible to use many cameras pointed on non-overlapping areas or, conversely, a single camera with a wide field of view. In the former case, the amount of data to be analyzed is much bigger than in the latter one. In addition, calibration and synchronization problems for the camera network have to be faced. On the other hand, in the second approach the system is cheaper, easy to calibrate, while the analysis of a single image is straightforward. In this case, however, the disadvantage is a loss of resolution at which objects details are seen, since a wider field of view is projected onto the same area of the video sensor and thus described with the same amount of pixel as for a normal one. This was clear since the mid 1990s with the earlier experiments with omnidirectional vision systems. Consequently a number of studies on omnidirectional sensors "enriched" with at least one second source of environmental data arose to achieve wide fields of view without loss of resolution. For example some work, oriented to robotics applications, has dealt with a catadioptric camera working in conjunction with a laser scanner as, to cite

only few recent, in (Kobilarov 2006; Mei 2006). More surveillance application-oriented work has involved multi-camera systems, joining omnidirectional and traditional cameras, while other work dealt with geometric aspects of hybrid stereo/multi-view relations, as in (Sturm 2002; Chen 2003).

The natural choice to develop a cheap vision system with both omni-sight and high-detail resolution is to couple an omnidirectional camera with a moving traditional camera. In the sequel, we will focus on this kind of systems that are usually called “hybrid dual camera systems”.

Omnidirectional Vision

There are two ways to obtain omnidirectional images. With a special kind of lenses mounted on a standard camera, called “fisheye lenses”, it is possible to obtain a field of view up to about 180-degrees in both directions. The widest fisheye lens ever produced featured a 220-degrees field of view. Unfortunately, it is very difficult to design a fisheye lens that satisfies the single viewpoint constraint. Although images acquired by fisheye lenses may prove to be good enough for some visualization applications, the distortion compensation issue has not been solved yet, and the high unit-cost is a major drawback for its wide-spread applications.

Combining a rectilinear lens with a mirror is the other way to obtain omnidirectional views. In the so called “catadioptric lenses” a convex mirror is placed in front of a rectilinear lens achieving a field of view possibly even larger than with a fisheye lens. Using particularly shaped mirrors precisely placed with

respect to the camera is also possible to satisfy the single viewpoint constraint and thus to obtain an image which is perspectively correct. Moreover, catadioptric lenses are usually cheaper than fisheye ones. In Figure 1 a comparison between these two kinds of lenses can be seen.

OVERVIEW OF HYBRID DUAL CAMERA SYSTEMS

The first work concerning hybrid vision sensors is probably the one mentioned in (Nayar 1997) referred to as “Omnidirectional Pan/Tilt/Zoom System” where the PTZ unit was guided by inputs obtained from the omnidirectional view. The next year (Cui 1998) presented a distributed system for indoor monitoring: a peripheral camera was calibrated to estimate the distance between a target and the projection of the camera on the floor. In this way, they were able to precisely direct the foveal sensor, of known position, to the target and track it. A hybrid system for obstacle detection in robot navigation was described in (Adorni 2001) few years later. In this work, a catadioptric camera was calibrated along with a perspective one as a single sensor: its calibration procedure permitted to compute an Inverse Perspective Mapping (IPM) (Little 1991) based on a reference plane, the floor, for both images and hence, thanks to the cameras’ disparity, to detect obstacles by computing the difference between the two images. While this was possible only within the common field of view of the two cameras, awareness or even tasks such as ego-motion estimation were potentially pos-

Figure 1. Comparison between image formation in fisheye lenses (left) and catadioptric lenses (right)



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