Chapter 49
Stereoscopic Vision for Off-Road Intelligent Vehicles

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ABSTRACT

After mechanization, the next disruptive technology in agriculture will probably be robotization. The introduction of information technology and automation in farm fields started in the eighties with the advent of the Global Positioning System (GPS) and the subsequent development of Precision Agriculture. While being indispensable for many innovative applications, global positioning is not sufficient for all situations encountered in the field, where local sensing is essential if accurate and updated, information has to control automated vehicles. Safeguarding, high resolution mapping, and real time monitoring can only be achieved with local perception sensors such as cameras, lasers, and sonar rangers. However, machine vision offers multiple advantages over other sensing alternatives, and among imaging sensors, stereo vision provides the richest source of information for real time actuation. This chapter presents an overview of current and future applications of 3D stereo vision to off-road intelligent vehicles, with special emphasis in real problems found in agricultural environments and practical solutions devised to cope with them, as image noise, system configuration, and 3D data management. Several examples of stereo perception engines implemented in robotized off-road vehicles illustrate the concepts introduced along the chapter.

INTRODUCTION

An intelligent off-road vehicle is a vehicle that, in addition to perform optimally in off-road environments, has been endowed with certain degree of artificial intelligence (AI). Typical equipment designed to work in off-highway conditions include agricultural machinery, forestry machines, construction vehicles, military trucks, and planetary rovers. The intelligent and automatic tasks typically demanded from these vehicles are directly related to the purpose or main activity for which they have been designed, although most of the instrumentation and techniques employed are common among off-road vehicles. This chapter focuses on off-road vehicles used for civilian applications,

DOI: 10.4018/978-1-4666-4607-0.ch049

especially those related with agricultural production systems. In this particular case, the objective is usually to assist operators so that vehicles can perform their tasks in *semi-autonomous mode*; that is, the driver sits in the cabin of the vehicle for supervision and security reasons while several tasks are carried out simultaneously, and some of them automatically. Unlike planetary rovers that cope with totally unstructured terrains, farm-based equipment often navigates through fields orderly arranged and partially structured by crop rows, tree lanes, guiding trellis, or greenhouse walls. Even those operations occurring in barren fields are limited by field boundaries, natural streams, or irrigation canals.

The presence of solid structures sharing the vital space used by intelligent vehicles in their regular motion is both an advantage and a disadvantage. The former is due to the fact that structures of known characteristics provide additional information to the vehicle and create visual features that can be tracked for navigation and localization. The latter, however, poses a critical problem for automated vehicles as most of the obstacles found in agricultural fields are not traversable and the possibility of having an accident is always present. In fact, this risk is most likely the hardest impediment to automation in agricultural fields, where intelligent machines, even in semi-autonomous mode– are assumed to outperform humans. The existence of semi-structured environments results in the need of reliable perception capabilities, and among the range of practical possibilities, machine vision occupies a preeminent position. It is, precisely, under these circumstances of partially structured terrains where stereoscopic vision finds its privileged niche as it provides three-dimensional (3D) representations of field scenes in the vicinity of intelligent vehicles, at high rates, and with a resolution never reached by satellite or airborne imagery. This chapter explains how to configure the stereo perception engine of an off-road vehicle, discusses the main issues and difficulties involved with real time 3D perception, proposes practical solutions to deal with common problems encountered in the field, and finally analyzes two popular applications within off-road agricultural equipment.

BACKGROUND

Although the principles of stereoscopy have been known since the nineteen century, the availability of commercial stereo cameras only dates from the turn of this century. The processing speed of current computers allows the execution of algorithms that can correlate two stereo images and generate a depth map in real time. The level of detail and amount of information supplied by stereoscopic perception has placed stereo-based devices in a privileged position among other sensors used in field robotics. Mars exploration (Olson et al., 2003) and defense mobile robots like Urbie rely on stereo cameras to acquire critical information of remote and often hazardous environments. The application of 3D vision technology to agricultural vehicles, in spite of having a high potential (Rovira-Más, 2003), is still in its infancy. Some timid efforts have been made to apply the idea of stereoscopy to automatically locate fruits in plants (Kondo et al., 1996), but human intervention has been normally required to assist in pixel matching. Real time stereo-based perception for mobile robots is relatively recent, and although some solutions have been successfully developed for small indoor robots (Herath et al., 2006) and on-highway vehicles (Kato et al., 1996), the scenarios typically perceived in these applications are substantially different from those encountered by off-road vehicles; therefore, the latter demand specific solutions motivated by very distinctive needs. Even the off-road prototypes that participated in the DARPA Grand Challenge competition, organized by the United States Department of Defense, were set to fulfill elaborated missions that nothing have to do with habitual agronomical tasks (Kogler et al., 2006).

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