An efficient omnidirectional vision system for soccer robots: From calibration to object detection


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A B S T R A C T

Robotic soccer is nowadays a popular research domain in the area of multi-robot systems. In the context of RoboCup, the Middle Size League is one of the most challenging. This paper presents an efficient omnidirectional vision system for real-time object detection, developed for the robotic soccer team of the University of Aveiro, CAMBADA. The vision system is used to find the ball and white lines, which are used for self-localization, as well as to find the presence of obstacles. Algorithms for detecting these objects and also for calibrating most of the parameters of the vision system are presented in this paper. We also propose an efficient approach for detecting arbitrary FIFA balls, which is an important topic of research in the Middle Size League. The experimental results that we present show the effectiveness of our algorithms, both in terms of accuracy and processing time, as well as the results that the team has been achieving: 1st place in RoboCup 2008, 3rd place in 2009 and 1st place in the mandatory technical challenge in RoboCup 2009, where the robots have to play with an arbitrary standard FIFA ball.

1. Introduction

The Middle Size League (MSL) of RoboCup is a forum where several research areas have been challenged for proposing solutions to well-defined practical problems. The robotic vision is one of those areas and, for most of the MSL teams, it has become the only way of sensing the surrounding world.

From the point of view of a robot, the playing field during a game provides a fast-changing scenery, where the teammates, the opponents and the ball move quickly and often in an unpredictable way. The robots have to capture these scenes through their cameras and have to discover where the objects of interest are located. There is no time for running complex algorithms. Everything has to be computed and decided in a small fraction of a second, for allowing real-time operation; otherwise, it becomes useless.

Real-time is not the only challenge that needs to be addressed. Year after year, the initially well controlled and robot friendly environment where the competition takes place has become increasingly more hostile. Conditions that previously have been taken for granted, such as controlled lighting or easy to recognize color coded objects, have been relaxed or even completely suppressed. Therefore, the vision system of the robots needs to be prepared for adapting to strong lighting changes during a game, as well as, for example, for ball-type changes across games.

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In this paper, we provide a comprehensive description of the vision system of the MSL CAMBADA team (Fig. 1). Cooperative Autonomous Mobile Robots with Advanced Distributed Architecture (CAMBADA) is the RoboCup MSL soccer team of the Institute of Electronics and Telematics Engineering of Aveiro (IEETA) research institute, University of Aveiro, Portugal. The team, which started officially in October 2003, won the 2008 MSL RoboCup World Championship and ranked 3rd in the 2009 edition.

We start by presenting and explaining the hardware architecture of the vision system used by the robots of the CAMBADA team, which relies on an omnidirectional vision system (Section 2). Then, we proceed with the description of the approach that we have adopted regarding the calibration of a number of crucial parameters and in the construction of auxiliary data structures (Section 3). Concerning the calibration of the intrinsic parameters of the digital camera, we propose an automated calibration algorithm that is used to configure the most important features of the camera, namely, the saturation, exposure, white-balance, gain and brightness. The proposed algorithm uses the histogram of intensities of the acquired images and a black and a white area, known in advance, to estimate the referred parameters. We also describe a general solution to calculate the robot centered distances map, exploring a back-propagation ray-tracing approach and the geometric properties of the mirror surface.

The soccer robots need to locate several objects of interest, such as the ball, the opponent robots and the teammates. Moreover, they also need to collect information for self-localization, namely, the position of the field white lines. For these tasks, we have developed fast and efficient algorithms that rely on color information.