



## A robust omnidirectional vision sensor for soccer robots

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### ABSTRACT

How to make robot vision work robustly under varying lighting conditions and without the constraint of the current color-coded environment are two of the most challenging issues in the RoboCup community. In this paper, we present a robust omnidirectional vision sensor to deal with these issues for the RoboCup Middle Size League soccer robots, in which two novel algorithms are applied. The first one is a camera parameters auto-adjusting algorithm based on image entropy. The relationship between image entropy and camera parameters is verified by experiments, and camera parameters are optimized by maximizing image entropy to adapt the output of the omnidirectional vision to the varying illumination. The second one is a ball recognition method based on the omnidirectional vision without color classification. The conclusion is derived that the ball on the field can be imaged to be an ellipse approximately in our omnidirectional vision, and the arbitrary FIFA ball can be recognized by detecting the ellipse imaged by the ball. The experimental results show that a robust omnidirectional vision sensor can be realized by using the two algorithms mentioned above.

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### 1. Introduction

The RoboCup Middle Size League (MSL) competition is a standard real-world test bed for autonomous multi-robot control, robot vision and other relative research subjects. In the past decade, omnidirectional vision system has become one of the most important sensors for the RoboCup MSL soccer robots, for it can provide a 360° view of the robot's surrounding environment in a single image. Robots can use it to realize object recognition [1], tracking [2] and self-localization [3,4] which provides perception information about the environment for robot control, planning, multi-robot cooperation and coordination.

The final goal of RoboCup is that the robot soccer team defeats human championship team, so robots will have to play competitions under highly dynamic even outdoor lighting conditions, and without the constraint of the current color-coded environment. According to the current rule of RoboCup MSL, the illumination is not specified, color goals have been replaced with white goal nets, color goalposts have been removed, and the technical challenge of playing with an arbitrary FIFA ball has been introduced. So there are two challenging research focuses in robot vision for soccer robots, although they have been researched for many years. First, it is still not easy to make vision system work robustly under varying lighting conditions in the color-coded RoboCup MSL environment [5]. The traditional methods, such as segmenting the image first

and then detecting the color blobs by using a color lookup table calibrated off-line, would not work well when the lighting condition fluctuates during the competition. Second, it is much more difficult to recognize generic objects such as ordinary FIFA balls than to recognize the color-coded objects such as orange balls. So it would be significant to develop robust omnidirectional vision sensors that can handle these issues for the improvement of the soccer robots' performance and the realization of the final goal of RoboCup. In this paper, the term "robustness" means not only that robot vision can work well and consistently under varying lighting conditions, but also that generic objects, like the FIFA balls with different colors and textures, can be well recognized.

Generally, the robustness of robot vision can be realized in the phase of image acquisition or in the phase of image processing [6]. The former one, which is often ignored by researchers, is to acquire images to describe the environment as consistently as possible under different lighting conditions by auto-adjusting camera parameters [1,7–9]. The camera parameters displayed here are image acquisition parameters, not the intrinsic or extrinsic parameters in camera calibration. The phase of image processing consists of many different approaches. For example, some researchers processed and transformed the images to achieve some kind of constancy, such as color constancy [10] by Retinex algorithm [11,12], and some others designed adaptive or robust object recognition algorithms [13,14]. So the images can be analyzed and understood robustly to a certain degree. In this paper, we also try to improve the robustness of our omnidirectional vision in image acquisition and image processing to deal with the two challenging issues for soccer robots. First, we propose a novel

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