



Arbitrarily colored ball detection using the structure tensor technique

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ABSTRACT

In this paper we present a new technique for ball detection in the RoboCup environment. The proposed method is an advanced version of the Hough transform and its main detection feature is local rotational invariance. This feature is utilized by means of the structure tensor technique, which optimizes linear parameters in partial differential equations within a local neighborhood. For our application we use the vanishing angular derivative describing the rotational invariance of the ball. Since no color information is used, the method can be used for the detection of any arbitrarily colored ball using a vision system. Compared to the standard version of the Hough transform for circle detection our version is a lot more robust, because the structure tensor technique directly provides the circles' center coordinates as well as the radii and the accumulator space is only used to improve accuracy.

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1. Introduction

The detection of the ball is one of the most important tasks in RoboCup and will become one of the most challenging ones with the introduction of arbitrarily colored balls. This leaves the outer shape of the ball as the only classification feature, especially if the ball has multi-colored patterns.

The task of detection the ball consists of determining three parameters, the coordinates in the image plane and the radius. Certain assumption can limit the search space, e.g. the assumption that the ball is on the ground. This however limits the situations where the ball can be detected. Since most teams can kick the ball in the air, it is crucial, especially for the goal keeper, not to include assumptions about the ball's radius. The new approach presented in this paper does not require any assumptions about the ball being on the ground.

Most teams use the Hough transform (see [2]), which is a feature extraction technique based on a voting procedure in the parameter space, also called accumulator array, spanned by the parameters describing the feature in the image, in our case the location and radius of the ball.

In its most basic version the Hough transform for circles each image pixel represents a circular cone surface which means that the parameter space gets quite crowded. This makes it difficult to search for local maxima which describe the desired solutions. Ballard [1] showed that the dimension of the accumulator array increment can be reduced from 2 to 1. This one dimensional object consists of one or two lines, depending on whether it is known or

not if the gradient point toward or away from the ball. With our approach we further reduce the dimension of the increment object to a single point.

2. Approaches currently used in RoboCup

In the past most ball detecting algorithms are based on color classification because of the balls distinct orange color. Starting this year, the rules stipulate the use of an arbitrarily colored ball which does not mainly consist of colors black, white and green. In the following we describe a few examples of approaches currently used in the RoboCup Mid Size League environment.

Neves et al. [10] use an algorithm based on search lines and color classification to determine the location of the ball, obstacles and white lines on the field. They apply this algorithm to catadioptric as well as perspective camera images. Voigtländer et al. [12] also uses scanlines and color classification to detect the ball as well as other objects of interest. They use a stereo vision system consisting of a catadioptric and a perspective camera allowing for 3D ball recognition.

Martins et al. [9] uses an edge detection followed by a circular Hough transform to estimate the location of the ball. They could show that the Canny filter is the best choice for detecting the edges in the image. Since this approach is not using color information, it can be used to detect arbitrarily colored balls. We will compare our new approach to this technique which uses the standard Hough transform.

Lu et al. [8] developed an algorithm that detects ellipses in images from an omni-directional vision system. They use a special mirror with a hyperbolic part in the middle, a horizontally isometric

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