

Arbitrary ball detection using the circular Hough transform

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Abstract

Given an arbitrary image and assuming that we are interested in locating a particular object, the goal of object detection is to determine whether or not there is any object of interest. This work is inserted in the RoboCup domain and is focused on the development of algorithms for the detection of arbitrary FIFA balls, an important object for soccer robots. We developed an algorithm to detect arbitrary soccer balls using morphological information given by the Canny edge detector and the circular Hough transform. Experimental results are presented, showing that the developed algorithm is accurate, being capable of reliable ball detection in real-time situations.

1. Introduction

Understanding the environment is a fundamental problem in the design of autonomous mobile robots. A basic part of perception is to detect and recognize objects. The performance of a mobile robot crucially depends on the accuracy, duration and reliability of its perceptions. Several autonomous robots use a computer vision system to understand the environment around it.

In this work, we developed an efficient vision system for an autonomous robot, designed to play football in the MSL (Middle Size League) competition of RoboCup. The official tournament ball used in matches is any orange FIFA ball. However, as from 2011, inclusive, it will be required to use an arbitrary official FIFA ball instead of a completely orange ball. Thus, we focused on the development of algorithms for the detection of arbitrary FIFA balls using morphological information.

Some research groups have already started to develop algorithms for color invariant ball detection. Many of the algorithms proposed during previous research work showed their effectiveness but, unfortunately, their processing time is, in some cases, over one second per video frame (see for example [3]).

2 Proposed approach

The proposed approach for arbitrary FIFA ball recognition is based on the morphological analysis of the acquired image. This approach is based on the use of image segmentation [2], the circular Hough transform [4] and the OpenCV library functions [1], being strictly directed to detect in the field round objects with specific characteristics, in this case the ball.

2.1 Circular Hough transform

The Hough transform (HT) is a technique for identifying the locations and orientations of certain types of features in a digital image [4]. The HT algorithm uses an accumulator and can be described as a transformation of a point in the x,y -plane to the parameter space. The parameter space is defined according to the shape of the object of interest, in this case, the ball presents a rounded shape.

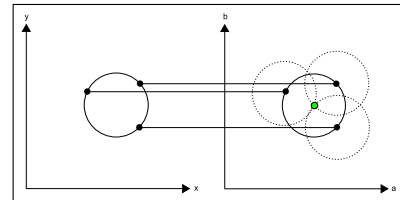


Figure 1. The circular Hough transform.

Figure 1 shows an example of a circular Hough transform, for a constant radius, from the x,y -space to the parameter space.

Figure 2 shows an example of circle detection through the circular Hough transform. We can see the original image of a dark circle (known radius r) on a bright background (see Fig. 2a). For each dark pixel, a potential circle-center locus is defined by a circle with radius r and center at that pixel (see Fig. 2b). The frequency with which image pixels occur in the circle-center loci is determined (see Fig. 2c). Finally, the highest-frequency pixel represents the center of the circle with radius r .

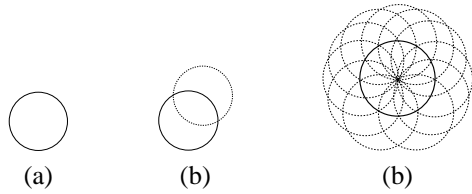


Figure 2. Example of a circle detection through the use of the circular Hough transform.

2.2 Proposed algorithm

The search for potential ball candidates is conducted taking advantage of morphological characteristics of the ball (round shape), using the circular Hough transform. To feed the Hough transform process, it is necessary a binary image with the edge information of the objects. We use some knowledge of the object of interest, in this case the radius of the ball according to the distance to the center of the robot. We know these values a priori, depending on the object and the resolution of the image, and they can be used by the Hough transform to optimize speed.

Relatively to the images creation (see Fig. 3), initially the image is acquired (Fig. 3a) and then it is segmented. Next, the segmented image is used to create the grayscale image based on green pixels (representing the playing field) and the non-green pixels. The image of contours (Fig. 3b) is obtained by applying the Canny edge detector [2] to the grayscale image. Finally, for all contour pixels obtained, the Hough image (Fig. 3c) is determined according to the example of Fig. 2. The maximum values obtained in this image are then validated using some heuristics to decide if we accept them as ball candidate or not.

3. Results and conclusions

In the experiments the ball was placed in a measured position in the field and the robot has performed a predefined tour while the position of the ball was registered. Since the aim is to detect arbitrary balls, four different official FIFA balls were used. Some results are presented in Table 1.

Ball	Std (meters)	Detection ratio (%)
1	(0.24 , 0.10)	84.7
2	(0.21 , 0.27)	100.0
3	(1.29 , 0.25)	97.6
4	(0.63 , 0.22)	94.7

Table 1. Some experimental measures obtained with four different balls.

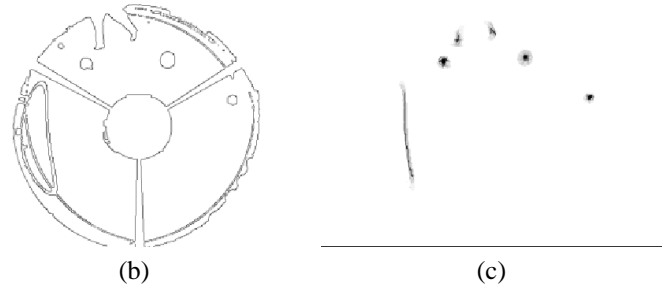
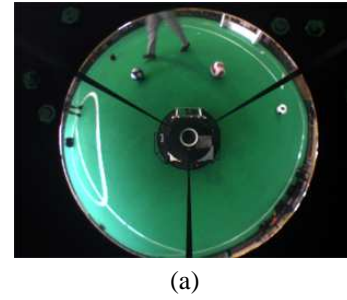


Figure 3. Example of a sequence of images transformation.

Taking into account that the analyzed contours are obtained using the acquired image segmentation, the shape of the ball depends on the color image. The more defined is the color image segmentation, closer to a circle is the form obtained. According to the results of Table 1, the algorithm provides frequent and almost always accurate ball detection.

Globally, the experimental results are promising. Moreover, the CAMBADA team achieved the 1st place in the “Arbitrary Ball Challenge” during the RoboCup2009 in Graz, Austria, where the algorithms were tested in a competitive environment.

References

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