

# Toward RoboCup without Color Labeling

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■ Object recognition and localization methods in RoboCup work on color-segmented camera images. Unfortunately, color labeling can be applied to object-recognition tasks only in very restricted environments, where different kinds of objects have different colors. To overcome these limitations, we propose an algorithm, called the CONTRACTING CURVE DENSITY (CCD) algorithm, for fitting parametric curves to image data. The method neither assumes object-specific color distributions, or specific edge profiles, nor does it need threshold parameters. Hence, no training phase is needed. To separate adjacent regions, we use local criteria that are based on local image statistics. We apply the method to the problem of localizing the ball and show that the CCD algorithm reliably localizes the ball even in the presence of heavily changing illumination, strong clutter, specularity, partial occlusion, and texture.

The rules of middle-size autonomous robot soccer require that different objects have distinct colors: The field is green with white lines; goals are blue and yellow; and robots are black with light blue or magenta markers, depending on the team they play for. These stringent rules allow for simple mechanisms for object detection and recognition: Segment the captured image into blobs of the same color and interpret these blobs. To the best of our knowledge, all autonomous robot soccer teams with vision-based perception apply variations of such a method. However, because the RoboCup committee is planning to make the rules more realistic, these object-

recognition and -localization methods are becoming obsolete.

In the context of the AGILO autonomous robot soccer team (Beetz et al. 2002), Hanek (2001) has developed the CONTRACTING CURVE DENSITY (CCD) algorithm for model-based image segmentation and object localization. We are currently integrating it into our probabilistic vision-based game-state estimation (Schmitt et al. 2002).

The CCD algorithm is started with vague a priori knowledge of relevant object contours defined by (1) a curve model describing the set of possible object contours and (2) a multivariate Gaussian distribution of model parameters describing the set of likely contours. The CCD algorithm refines this a priori distribution to a Gaussian approximation of the posterior distribution by iterating two steps:

First, learn local statistics of image data by (1) computing pixels in the vicinity of the image curve and assigning them vaguely to a side of the curve and (2) computing the local image statistics for both curve sides from the corresponding pixels. The local statistics define an expectation of “how the two sides of the curve might look.”

Second, refine the estimation of model parameters by (1) updating the mean of the estimation in a maximum a posteriori step such that the vicinity of the curve matches the expectation defined by the local statistics and (2) updating the covariance of the estimation based on the Hessian of the resulting objective function.

The two steps are repeated until there is no significant change in the estimated Gaussian distribution.



Figure 1. Initial Contour.



Figure 2. Initial and Estimated Contour.

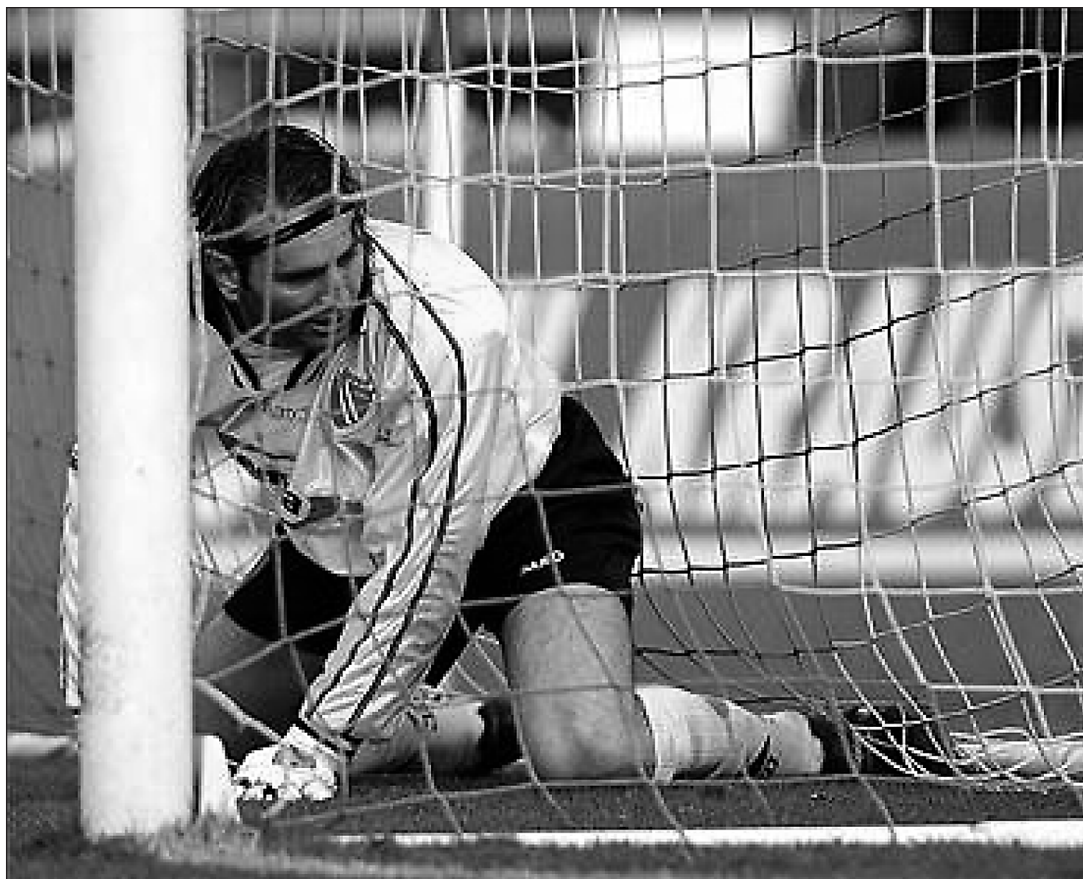
The CCD algorithm has several important advantages. It neither assumes object-specific color distributions or specific edge profiles, nor does it need threshold parameters. Hence, no training phase is needed. The CCD algorithm also achieves high robustness and accuracy. Furthermore, it allows the fusing of multiple sources of uncertain information possibly sensed by different robots.

We apply the method to the problem of localizing a soccer ball and show that the CCD algorithm reliably localizes the ball and other objects even in the presence of heavily changing illumination, strong clutter, specularly,

partial occlusion, and texture (Hanek et al. 2002). Some results of the CCD algorithm are depicted in figures 1 to 4.

#### References

- Beetz, M.; Buck, S.; Hanek, R.; Schmitt, T.; and Radig, B. 2002. The AGILO Autonomous Robot Soccer Team: Computational Principles, Experiences, and Perspectives. Paper presented at the First International Joint Conference on Autonomous Agents and Multiagent Systems, 15–19 July, Bologna, Italy.
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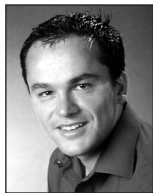


*Figure 3. Localization of a Soccer Ball.*

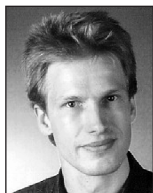


*Figure 4. Localization of a Mug.*

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