An overview on the application of machine vision in soccer robots

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Abstract—Robotic vision joins research challenges arrising from two different research areas: machine vision, as well as robotics. For soccer player robots, the aspects of full autonomy and real-time reaction are probably the most important ones that must be considered when developing a vision system. This paper presents an overview on the state of the art implementations and algorithms used in vision systems for robots playing soccer in the RoboCup competitions.

1. Introduction

Just like humans, robots can "sense" the surrounding world by means of different sensors, but usually, the vision system is their main sensorial element since it is capable to provide a great amount of information such as spatial, temporal and morphological.

In robotic soccer, the environment is always changing, the ball and the robots are always moving, most of the time in an unpredictable way. The vision system is responsible for capturing all these fast changing scenes, processing them and taking valid decisions in the smallest possible amount of time, thus allowing real-time reactions.

This paper is structured in 6 sections, as follows: Section 2 gives an overview on the RoboCup initiative with emphasis on the RoboCup Soccer Leagues. Section 3 focuses on the most recent implementations of vision systems used in the Middle Size League. In Section 4 the Standard Platform League is detailed in terms of most common and novel approaches for implementing the vision systems of the robots. Section 5 focuses on the Humanoid League. Finally, Section 6 concludes the paper.

2. The RoboCup initiative

RoboCup is an international initiative that fosters research in robotics and artificial intelligence, on multi-robot systems in particular, through competitions like RoboCup Robot Soccer, RoboCup Rescue, RoboCup@Home and RoboCupJunior. The main focus of the RoboCup competitions is the game of soccer, where the research goals concern cooperative multi-robot and multi-agent systems in dynamic adversarial environments.

The RoboCup Robot Soccer competition is divided into the following leagues: Middle Size League (MSL), Standard Platform League (SPL), Humanoids League (HL), Small Size League (SSL) and Simulation League, which will not be detailed in this paper.

3. The Middle Size League

In the context of RoboCup, the Middle Size League (MSL) is one of the most challenging. In this league, each team is composed of up to 6 robots with a maximum size of $50cm \times 50cm$ width, $80cm$ height and a maximum weight of $40Kg$, playing in a field of $18m \times 12m$.

Many teams are currently taking their first steps in 3D ball information retrieving [1], [2], while also developing vision systems capable of detecting balls without a specific color [1], [3]. There are also some teams moving their vision systems algorithms to VHDL based algorithms taking advantage of the FPGA's versatility [1]. Even so, for now, the great majority of the teams base their image analysis in color search using radial sensors [4], [5], [6].

4. The Standard Platform League

In the Standard Platform League, all teams compete using the same robotic platforms, therefore all efforts are focused on software developments. Currently, the standard robotic platform is the NAO robot, designed by Aldebaran.These robots come equipped with 2 video cameras, however stereo vision is yet not allowed. In this league, robots play in teams of up to 4 players, on a field with a length of $6m$ and a width of $4m$. The ball used is an orange hockey ball.

For the color segmentation of the image, most teams choose the approach of scan lines. That is, the image is scanned either horizontally, vertically, or in both directions [7], [8] while looking for one of the colors of interest. Other approach is to segment images in regions of interest, to whom probabilities are assigned [9]. The information about a color of interest segmented is validated in most cases if there is a given threshold of green color in the proximity of the color of interest previously segmented [7], [8], [10].

Different approaches instead of simple color segmentation as a first step in processing the image are proposed in [11], [12], [13]. In [11] the vision system is mostly based on pattern recognition. The ball recognition algorithm is based on detecting a circle and filtering undesired noise. Regarding goal perception, scan lines segmentation combined with fuzzy logic detection have been used. [13] propose a vision module based on Reinforcement Learning with Decision Trees Algorithms.

5. The Humanoid League

In the Humanoid League, the soccer players are autonomous robots with a body imitating the human body.

There are three size classes in this league: KidSize (the height of the robots is between 30 and 60cm, TeenSize(100-120cm) and AdultSize(130cm). In the KidSize soccer competition teams of three, highly dynamic autonomous robots compete with each other. Since 2010 the TeenSize soccer competition features teams of two autonomous robots competing with each other. In AdultSize soccer, a striker robot plays against a goal keeper robot first and then the same robots play with exchanged roles against each other.

The vision systems of the teams participating in this league are based on standard webcams [14], [15], [16]. Similar to the approaches presented in the SPL Section, the teams focus on color segmentation and extraction of certain measurements of the segmented color blobs in order to decide if a region of a given color is an object of interest or not [14], [17]. In [18] they estimate the distance and angle to each feature by removing radial lens distortion and by inverting the projective mapping from field to image plane. All teams mention the use of a look-up-table in order to replace computational operations when labelling the colors of interest, with array operations [18], [19], [20].

In [21], [22], [23], [24], [25] the same algorithms based on scan lines, color segmentation followed by different thresholding methods or computation of several relevant measurements are presented. The only main differences can be found in the choice of the color space used for processing the image.

6. Conclusions

This paper presented an overview of the currently methodologies used for the implementation of the vision systems used in different types of soccer robots. Although similar in certain aspects, the implementations presented differ in many aspects, from image acquisition, using different color spaces, image segmentation based on different types of information, to the choice of algorithms used for the detection of tracking of the objects of interest.

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