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A case-based approach for coordinated action selection in robot soccer

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ABSTRACT

Designing coordinated robot behaviors in uncertain, dynamic, real-time, adversarial environments, such as in robot soccer, is very challenging. In this work we present a case-based reasoning approach for cooperative action selection, which relies on the storage, retrieval, and adaptation of example cases. We focus on cases of coordinated attacking passes between robots in the presence of the defending opponent robots. We present the case representation explicitly distinguishing between controllable and uncontrollable indexing features, corresponding to the positions of the team members and opponent robots, respectively. We use the symmetric properties of the domain to automatically augment the case library. We introduce a retrieval technique that weights the similarity of a situation in terms of the continuous ball positional features, the uncontrollable features, and the cost of moving the robots from the current situation to match the case controllable features. The case adaptation includes a best match between the positions of the robots in the past case and in the new situation. The robots are assigned an adapted position to which they move to maximize the match to the retrieved case. Case retrieval and reuse are achieved within the distributed team of robots through communication and sharing of own internal states and actions. We evaluate our approach, both in simulation and with real robots, in laboratory scenarios with two attacking robots versus two defending robots as well as versus a defender and a goalie. We show that we achieve the desired coordinated passing behavior, and also outperform a reactive action selection approach.

1. Introduction

In order for a robot to perform an apparently simple task, such as actuating a ball towards a goal point, the robot needs multiple capabilities, including object detection, perception of the environment, building of an internal world model, making decisions when planning the task, navigation while avoiding obstacles, execution of planned actions, and recovering from failure. The complexity of each individual ability, and therefore the overall robot's behavior design, is related to the complexity of the environment where the robot carries out the task: the higher the complexity of the environment, the more challenging the robot's behavior design. Robot soccer is a particularly complex environment, particularly due to its dynamic nature resulting from the presence of multiple teammate and opponent robots.

In general in multi-robot domains, and robot soccer in particular, collaboration is desired so that the group of robots work together to achieve a common goal. It is not only important to have the agents collaborate, but also to do it in a coordinated manner so that the task can be organized to obtain effective results. A wide variety of methods has been investigated to address multi-agent coordination, including task division with role assignment [11,45,47], and establishment of mutual beliefs of the intentions to act [12]. Communication among agents underlies these approaches for collaboration.

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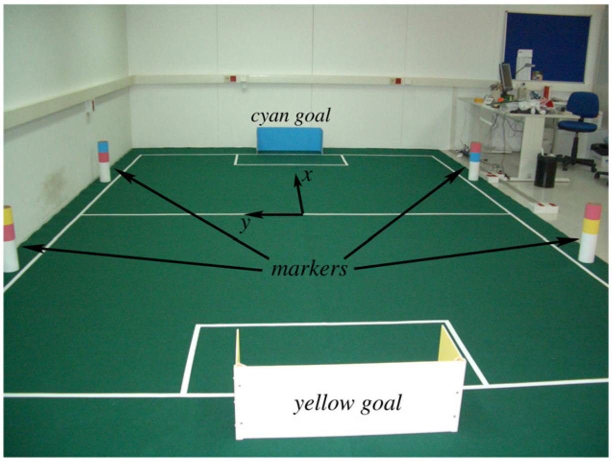

Fig. 1. Snapshot of the Four-Legged League field (image extracted from the IIIA lab).

In this work, we are particularly interested in the action selection and coordination for joint multi-robot tasks, motivated by a prototype environment of robot soccer. We have successfully applied Case-Based Reasoning (CBR) techniques to model the action selection of a team of robots within the robot soccer domain [37–39]. However, our previous approach did not address the dynamic intentional aspect of the environment, in particular, in robot soccer, the presence of adversaries. Many efforts aim at modeling the opponents [1,13,27,28,44,49], in particular when the perception is centralized [34]. Instead, we address here a robot soccer framework in which the robots are fully distributed, without global perception nor global control, and can communicate.

We follow a CBR approach where cases are recorded and model the state of the world at a given time and prescribe a successful action [19,25,33,48]. A case can be seen as a recipe that describes the state of the environment (problem description) and the actions to perform in that state (solution description). Given a new situation, the most similar past case is retrieved and its solution is reused after some adaptation process to match the current situation. We model the case solution as a set of sequences of actions, which indicate what actions each robot should perform [48]. Our case-based approach is novel in the sense that our cases represent a multi-robot situation where the robots are distributed in terms of perception, reasoning, and action, and can communicate. Our case-based retrieval and reuse phases are therefore based on messages exchanged among the robots about their internal states, in terms of beliefs and intentions.

Our case representation ensures that the solution description in the cases indicates the actions the robots should perform; that the retrieval process allocates robots to actions; and finally, with the coordination mechanism, that the robots share their individual intentions to act. Our approach allows for the representation of challenging rich multi-robot actions, such as passes in our robot soccer domain, which require well synchronized positioning and actions.

Previously, our retrieval process consisted of obtaining the most similar case based on two measures: similarity between the problem to solve and a given case, and the cost of adapting the problem to that case. Opponents were static, and therefore, simply modeled as obstacles the robots had to avoid [37]. We extend the retrieval algorithm to include an applicability measure that determines if the reuse of a given case is feasible or not, as a function of the opponent and despite its static similarity degree. Furthermore we view the position of the opponents and the ball in a case description as uncontrollable features, while the positions of the teammate robots are viewed as controllable features, in the sense that robots in the current situation can move to match the positions in the past cases.

In terms of the reuse step, before the robots start executing the assigned actions according to the case, they pre-position themselves in the initial positions of the retrieved case. Instead of following an independent positioning strategy [37], we propose an alternative positioning strategy that reduces the time spent on satisfying the initial conditions. We show empirical results that confirm the effectiveness of our collaborative approach compared to an individualistic approach. The scenarios include two moving opponents and two attacking robots.

The article is organized as follows. Section 2 presents our particular robot soccer domain and describes the case representation. Section 3 introduces the case retrieval in terms of matching the situation. Section 4 focuses on the multi-robot architecture for case retrieval and case reuse in our distributed multi-robot system. Section 5 presents the empirical evaluation. We review related work within the robot soccer domain in Section 6. Finally, Section 7 draws the conclusions and discusses future work.

2. Case-based representation of robot soccer play

Our work is prototyped within the RoboCup robot soccer research initiative RoboCup [35], which aims at creating a team of soccer robots capable of beating the human worldcup soccer champions by 2050 [17]. RoboCup includes several