Team/goal-keeper coordination in the RoboCup mid-size league

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Abstract. In this paper we describe the coordination strategies that were designed to achieve effective cooperation between a robot goal-keeper and the rest of the ART (Azzurra Robot Team) team that participates in the RoboCup F-2000 (mid-size) competitions.
The paper introduces the multi-robot environment on which cooperation in ART is based and, in particular, its communication sub-system. Some case studies and the results of their application in the ART team are then described.

1 Introduction

In this work coordination is discussed in the framework of the RoboCup, the Robot World Cup initiative, an international research activity aimed at fostering robotics and artificial intelligence technologies using soccer as a common task [1]. Azzurra Robot Team (ART), the Italian RoboCup team, is a national project involving several academic groups in a consortium [1]. The goal of the project is to exploit the expertise and ideas from all groups and build a team where players have different hardware and software features but have the ability to coordinate their behavior within the team.

More precisely, in this paper we describe some general coordination strategies used in ART and, more in particular, the ones that have been designed to achieve cooperation between the goal-keeper and the rest of the ART team in the RoboCup mid-size competition.

2 Coordinating a team of heterogeneous robots

Coordination of robot soccer players in the ART Team was particularly challenging because of a unique characteristic of the team which was clearly visible during the matches: each robot is the research effort of one member of the ART consortium. Therefore, each robot in ART differs from its team mates in many ways: mechanics, sensors,

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[1] ART (http://robocup.ce.unipr.it) is a cooperative effort of “Consorzio Padova Ricerche”, Polytechnic of Milan, University of Genoa, University of Milan “Bicocca”, University of Padua, University of Parma, and University of Rome “La Sapienza”

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computer hardware and control software but most of all designer. The designer in particular was not only different but also operated in a substantially independent way and with not so frequent communication with the other members of the team (due to the distance between the different university sites). This led to a truly heterogeneous team in which the role of coordination became therefore very significant. Coordination was dealt with at two different levels described in the next subsections.

2.1 Low-level communication framework

The low level communication framework is strictly related to the ETHNOS [2] real-time [3, 4] software architecture which was at the base of inter-robot communication in ART. ETHNOS in fact exploits a message-based communication protocol (the EIEP - Expert Information Exchange Protocol [5]) which deals transparently both with inter-process communication within a single robot and with inter-robot communication. Messages are exchanged with a publish/subscribe technique and dynamically distributed by the system to the appropriate receivers.

It is worth noticing that, even though ETHNOS is platform-dependent (it requires a Posix RT(r) compatible kernel such as Linux with RT threads), the EIEP is a more general protocol that runs on any system that provides socket communication. Moreover ETHNOS does not constrain the Robot physical or higher level software control archicteture and it has in fact been exploited on the different robots that compose the ART Team. Another important property of the system is the automatic management of agents connection and disconnection. In fact, whenever we want to add (remove) a player to (from) the team, it is not necessary to explicitly inform each player about the modifications in the team's composition. Players just have to agree about the type of information they are ready to send and receive, and ETHNOS deals automatically with the lower level communication details. This has been very important in ART in which more than four types of robots were available, with different characteristics of play, and thus different team compositions were selected for the single matches and also modified during the matches to better contrast the opponent.

2.2 Coordination protocol between the players

Coordination in ART was based on the underlying EIEP described above. The goal-keeper was coordinated in a separate way as described in section 3, and the other three players were organized in a formation with specific roles dynamically assigned during the match. Utility functions and hysteresis were exploited to carry out the dynamic role assignment every 100 milliseconds in an efficient and stable manner. More details on this coordination strategy can be found in [6].

3 Team/goal-keeper coordination: case studies

This section describes some cases of coordination between the goal-keeper and the other players that were specifically studied in designing the autonomous robot shown in figure 1 that plays as goal-keeper in the mid-size ART team [7].

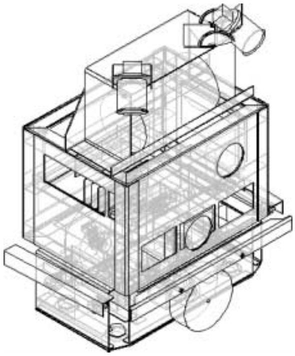


Fig. 1. The ART goalie Galavrón and its CAD model: two wide-angle cameras are on the top. The wheels are mounted in the middle of the chassis. The pneumatical kicking devices located in the lower part are driven by an air tank placed inside the camera holder.

The goalie's role and position inside the field has strongly influenced and constrained its mechanical design, its motion strategy, as well as its software architecture. The latter consists of a multi-Agent system composed of three Agents: a Visual Perception Agent that provides the robot with vision; a Goal-Keeper Agent that provides decision-making skills and controls the motion of the goalie; and a Cooperative Agent which enables the robot to cooperate and co-ordinate its activities with the other robot players [8, 6].

The robot operation is influenced by both the cooperation among the software agents within the robot and the interaction of the robot with its team-mates, that permits to integrate and enhance information about the environment that the robot acquires autonomously.

Critical situations in which goalkeeper/players coordination strategies can be effectively used fall into two major categories, which we may term *implicit* and *explicit coordination*, respectively:

– Goalie's replacement or support: these are situations in which the goalie's performance is impaired by hardware faults, self-localization faults or perceptual limitations. In this case team-mates can realize what is happening and take appropriate countermeasures.
– Defensive behaviors of the players triggered by explicit requests from the goalie.

In figure 2-a.1 the goalie gets stuck and has to be taken out of the field. In this case, the hardware failure is detected when no messages are received from the goalie for a preset amount of time. Consequently (figure 2-a.2), the other team members back up: one player patrols the goalie's operating region (as far as rules allow to do so, which means just outside the goal-keeper area), while one of the other two players takes the Main Defender role.

In figure 2-b.1, the goalie has moved away from the goal, possibly as a consequence of a failure of its self-localization system. This event can be detected by the vision

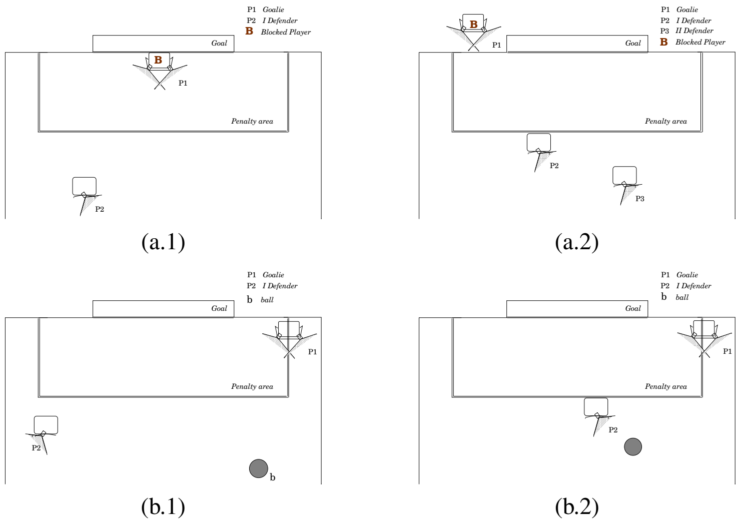

Fig. 2. Two examples of implicit team/goalie coordination: a) the goalie is stuck; b) the goalie is out of position.

system of the closest team-mate. In this case, the team-mate can go to shield the goal (within the above-mentioned limits), until the goalie recovers its correct position.

Another critical situation is the one in which the goalie's view is occluded by another robot that keeps the ball out of the goalie's sight. In this case the goalie can use information about ball coordinates provided by the team-mate and move to the optimum position. This is a very significant example of cooperation that has been successfully tested even in an extreme situation in which the goalie is totally blind (see also section 4).

Figure 3 shows two examples of defensive actions triggered by an explicit request from the goalie. In the first example the goal is threatened by two opponents that could easily elude the goalie's intervention by passing the ball between each other. In this case the goalie explicitly calls back a defender; the latter backs up and obstructs the free space between the opponents, preventing the pass from occurring. In the second example a team-mate lies on the optimal trajectory that the goalie should give the ball in order to send it away from the goalkeeper area (figure 3-a). The goalie then sends a message to the team-mate to make it back up and leave enough space for its sweeping shot to occur (figure 3-b).

4 Experimental results

Some of the previously described situations have been tested in the practice. In a particularly significant experiment the vision system of the goal-keeper had been switched off, so that the goal-keeper was totally blinded and could perceive the surrounding world only through the messages sent by a team-mate that was observing the ball. Such messages replaced the input to the Goal-Keeper Agent, that is usually provided by the Vi-

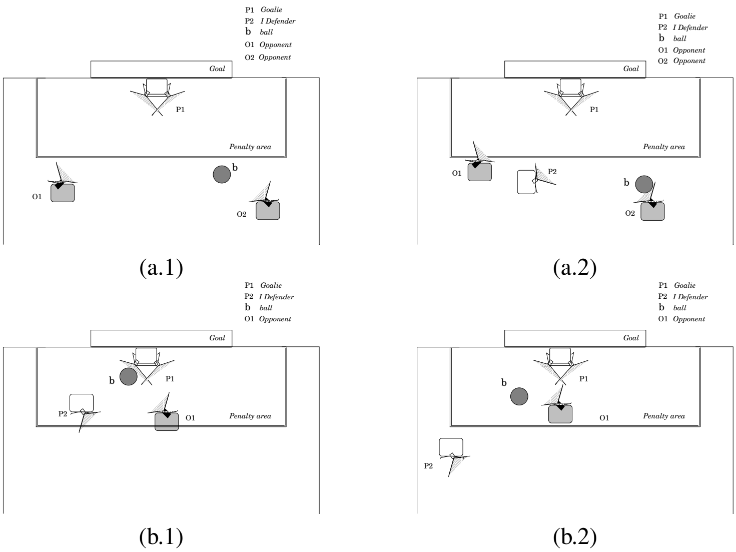

Fig. 3. Two examples of explicit goalie/team coordination: a) the goalie calls back a player; b) the goalie sends a mate away.

sual Perception Agent. Figure 4 shows the setup that has been used for the experiment. The goalie performed quite well, showing basically the same behaviors as in normal operating conditions, with no apparent decay of the reaction time.

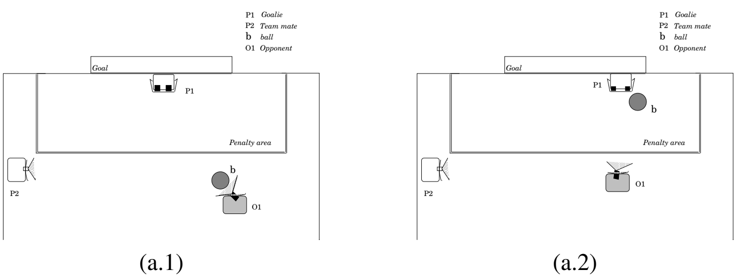

Fig. 4. The goalie is blinded but can operate using the team-mate's messages

This experiment, besides showing the intrinsic effectiveness of the coordination strategies, reflects situations that can occur in several real-world environments in which robots operate. The opportunity of supporting a temporarily or permanently impaired robot in a team with information coming from its mates, creates a "perceptual redundancy". Exploiting such redundancy may be very important, if not crucial, in several critical tasks, especially when robots operate in regions that are unsafe for humans, or possibly in unmanned space exploration missions.

5 Final remarks

In teams of heterogeneous robots where each player typically has to play a different role an effective coordination strategy is a key component of the team's successful design. The importance of cooperation strategies is getting more and more significant in the F-2000 RoboCup League, where game quality is rapidly evolving from simple individual "locate the ball and shoot" behaviors to more complex and team-oriented ones.

In this paper we have focussed on the coordination between the ART goalkeeper and the rest of the team. Examples have been shown of situations in which such coordination is essential, both when it occurs implicitly as the result of a one-side reasoning process derived from a message broadcast and when it is explicitly implemented through a message exchange between players. Some of the described situations could be already coped with successfully by the coordination strategy used in the past competitions; the global coordination strategy is now being updated to cope with the remaining ones and with new ones in future editions of RoboCup.

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