Synthesized Cooperative Strategies for Intelligent Multi-Robots in a Real-Time Distributed Environment

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Abstract

In the robot soccer domain, real-time response usually curtails the development of more complex AI-based game strategies, path-planning and team cooperation between intelligent agents. In light of this problem, distributing computationally intensive algorithms between several machines to control, coordinate and dynamically assign roles to a team of robots, and allowing them to communicate via a network gives rise to real-time cooperation in a multi-robotic team. This research presents a myriad of algorithms tested on a distributed system platform that allows for cooperating multi-agents in a dynamic environment. The test bed is an extension of a popular robot simulation system in the public domain developed at Carnegie Mellon University, known as TeamBots. A low-level real-time network game protocol using TCP/IP and UDP were incorporated to allow for a conglomeration of multi-agent to communicate and work cohesively as a team. Intelligent agents were defined to take on roles such as game coach agent, vision agent, and soccer player agents. Further, team cooperation is demonstrated by integrating a real-time fuzzy logic-based ball-passing algorithm and a fuzzy logic algorithm for path planning.

Keywords

Artificial Intelligence, Ball Passing, the coaching system, Collaborative, Distributed Multi-Agent, Fuzzy Logic, Role Assignment

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1 Research Description

1.1 Introduction

The robot soccer game, since its inception in 1987 was aimed at providing the research community with an exciting and fertile ground for artificial intelligence, machine vision, communications, control systems, sensor data fusion, multi-agent, mechanical and electrical integration, decision-making and response, artificial life and multi-robotics researches among many others.

This research endeavor extends the computing capabilities and complexity of cooperation between multi-agent by harnessing a distributed system approach, while ensuring that real-time decision schemes could be executed. A network game protocol is built on top of an existing popular robot soccer simulation platform developed at Carnegie Mellon University, known as TeamBots. The system allows for the participation of a multitude of computers interconnected to form and control a robot soccer team. The distributed system is comprised of a vision agent, intelligent coach, and robot soccer players and each could be run on a separate machine. The main impetus is that each robot is allowed to perform complex tasks, given a role that is dynamically assigned by the coach, depending on the game situation. Each robot in turn, performs target pursuit, obstacle avoidance, ball dribbling, ball passing and ball shooting independently of the others. With the aid of an intelligent coach, full-cooperation between the robots is made feasible. As an example, experiment results demonstrate how ball-passing is improved between players by utilizing a fuzzy logic-based approach. Moreover, role allocation is passively computed by the coach to designate the best candidate robot most suited for a given role (e. g. goal keeper, attacker, defender, support, etc.). All these cooperating multi-agent and the artificial intelligence inculcated in them were tested in an actual intranet connection that passes through the complete IP stack. The system performance was measured and evaluated and were shown to run all in real-time.

1.2 Research Objectives

The primary objectives of this research are:

1. To design and implement a real-time Supervised Multi-Agent System (SMAS) for coordinating a team of robots in a distributed environment (discussed in Sec. 3.3).
2. To develop a real-time network communication protocol and fuse it with the TeamBots robot soccer engine (Sec. 3.4).

3. To develop an algorithm for role allocation in a changing environment (Sec. 3.5).
4. To develop an adaptive fuzzy logic control system for ball passing between multi-agents and enhance their cooperation (discussed in Sec. 3.6).

1.3 Significance of the Research

This research proposes SMAS in order to achieve real-time multi-agent collaboration and more efficient delegation of algorithm computation among agents (Sec. 3.3). Contrary to non-supervised multi-agent systems, the proposed architecture allows for more complex algorithms to be deployed among agents, allowing for independent path-planning. An intelligent coach is designated to device the team's strategy, allocating specific roles to each member of the team (Sec. 3.5). This approach significantly reduces redundancy of role assignments and enhances team cooperation.

1.4 Overview the Problem Domain: Robot Soccer

1.4.1 RoboCup

RoboCup is an attractive international competition that poses an interesting problem in the planning of coordinated motion of individual players as a team against an opponent team. It aims to promote researches on real-time searching for an optimal coordinated motion of the intelligent agents. The ultimate goal of the RoboCup project is that by 2050, a team of fully autonomous humanoid robots that can win against the human world champion team in soccer will be developed [27].

Related events:

(1) Small Size League (diameter of less than 15 cm)

Figure 1 Small size league of RoboCup [27]

(2) Middle Size League (15 cm <((50 cm)

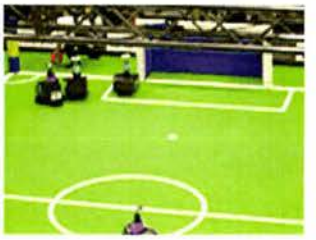

Figure 2 Middle size league of RoboCup 2004 [27]

(3) Simulation League

Figure 3 Simulation league of RoboCup [27]

(4) Four-Legged League

Figure 4 Four-legged league [27]

(5) Humanoid League

Figure 5 RoboCup 2006 humanoid [27]

1.4.2 FIRA Cup

FIRA Cup is yet another world-wide robotics project that promotes research on autonomous mobile robotic intelligent systems. It is a research initiative that helps generate interests among the young generation to be involved with cutting-edge technology researches. The impact of these researches is believed to change the future life of mankind in a variety of ways.

1.4.3 Artificial Intelligence in Robot Soccer

Artificial Intelligence (AI) is the core of research that this study aims to contribute in. Inculcating intelligence in a team of robots to make them autonomous, cooperative and adaptive to a dynamic hostile environment is the focus of this research. To mention a few of the candidate algorithms suitable for this problem, we have the following AI technologies:

1. Fuzzy logic is deemed to be very much suitable for robots motion control [8], such as role assignment [24],collision avoidance problem [7] and path planing [22]. It is in fact, a precise problem-solving methodology and utilizing the approach can result to higher accuracy and smoother control. The technique mimics the way humans think, allowing for vague description of the solution in terms of fuzzy rules. Fuzzy logic is regarded to be a promising technology with products worth hundreds of billions now available in the market.

2. Neural network in [20] and Q-learning referred in [18] are popular AI techniques that are suitable for the robot soccer problem domain. The paradigm could be utilized to allow robots to learn from the environment by interaction. The learning mechanism behind Neural Networks imitates the communication process in the central nervous system, involving neurons. Through a network of neurons working together to perform some global task, the system as a whole could exhibit complex global behaviors.

3. The A* algorithm is also one good candidate algorithm as it is an optimal path planning technique.

4. Alpha-beta pruning is not commonly used in the robot soccer game strategies currently, but it can be used for improving decision-making in the game.

5. Hybrid intelligent approaches, like the combination of any of the mechanisms above, such as path planning that combines algorithms like Fuzzy logic and A* is also being reported to be an excellent option in the literature [2].

1.4.4 Multi-Agent Roles, Strategies and Tactics

There are some common strategies and algorithms in robot soccer matches:

1. Dynamic role assignment is one important mechanism that could be employed in the game. Depending on various situations, robots are assigned varying roles to be a more effective member of the team with different action selection mechanisms and action selection problem is also widely researched, such as in

[11] and [19].

2. The goal keeper position is assigned to only one robot per team; therefore, this position is deemed to be of extreme importance, as it dictates largely the result of the competition. Most teams are prioritizing in developing intelligence for the goalie position.

3. Ball passing enhances the efficiency of coordination and team work. Therefore, this strategy translates to better team performance, and yet another factor that could lead to the domination of the game.

4. Target pursuit, is a fundamental algorithm necessary for retrieving the ball and taking control of it. However, a target is not necessarily just a physical object. Algorithms for target pursuit are also used for blocking an opponent or intercepting the ball.

5. Path planning is crucial to the game and has been widely researched on in general. It takes into account obstacles along the path and should be executed in real-time. The A* algorithm is one powerful technique for finding the shortest path to any destination objects. ERRT [5] is another solution to solve the time required path planing problem.