FC Portugal 2005 Rescue Team Description: Adapting Simulated Soccer Coordination Methodologies to the Search and Rescue Domain

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Abstract: FC Portugal Rescue team is the result of a cooperation project between the Universities of Aveiro and Porto in Portugal. The project started in January 2004 following previous collaborations of these two Portuguese Universities in RoboCup simulation league and associated competitions: coach competition, simulation league presentation competition and simulation 3D competition. FC Portugal Rescue project intends to fully adapt the coordination methodologies developed by FC Portugal simulated soccer team to the search and rescue scenario. Although our team was not ready for participating in RoboCup 2004, the first results achieved were very encouraging, making us believe that, after fully implementing our simulated soccer coordination methodologies in our rescue team, our result may be a lot better.

1. Introduction

Search and rescue in disaster situations is a very serious social issue which involves a large number of heterogeneous agents working together as a team in difficult conditions in a very hostile environment. RoboCup Rescue international project intends to promote research and development in this socially significant domain at various levels involving multi-agent team work coordination, development of physical robotic agents for search and rescue, development of information infrastructures, personal digital assistants and standard rescue simulators and visualizators.

RoboCup Rescue Simulation Project is a now well established RoboCup [1] competition intended to promote research on this very serious social problem. The development of the RoboCup rescue simulator [2,3] offered a new practical domain for RoboCup and enables the application of research results achieved in RoboCup soccer competitions to a more sociably useful problem. Our team explores exactly this line of research, adapting successful coordination methodologies from RoboCup Soccer simulation league to the Rescue Simulation League.

The simulator (figure 1) is based on a generic urban disaster environment built using a network of computers. Several types of heterogeneous autonomous agents such as fire brigades, ambulances, police cars and civilians are faced with a search and rescue virtual scenario in which saving human lives and city infrastructures is the main objective in order to minimize disaster damage.

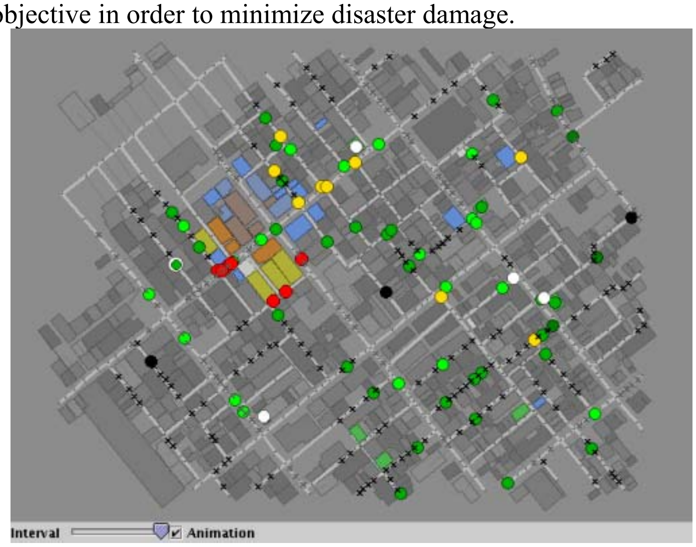

Fig.1: RoboCup Rescue Simulated Environment

For robotics and multi-agent researchers, RoboCup Rescue works as a standard platform that enables easy comparison of research results. The problem introduced by RoboCup Rescue brings up several research challenges that go from Intelligent Robotics to Multi-Agent Systems (MAS) research. These research challenges include real-time flexible planning, multi-agent coordination and team formation, low-bandwidth multi-agent communication, path planning and navigation, heterogeneous resource allocation and machine learning at the team level.

2. Team Development and Low-Level Decision

Since we are mainly interested in researching new coordination and learning methodologies, in order to abstract from lower-level rescue simulation details we started our team by using the available YowAI 2003 source code [4]. After some time and after gaining some experience with the simulator we decided to move to a different approach and concluded that in order to be able to run efficiently most of our planned algorithms we need a more efficient language. Thus, we moved to C/C++ code using as a reference Michael Bowling Agent Development Kit and SOS 2003 source code [17]. This conclusion is, however, contradictory with the fact that most of the more successful teams in RoboCup Rescue use Java as base language for developing their agents. However since most of our RoboCup teams are implemented using C++[1], it is a lot easier to adapt our code to a Rescue team implemented also in C++.

[1] FC Portugal Simulation 2D, Simulation 3D, Coach Team, FC Portus legged team and Cambada Middle-Size team are all implemented in C/C++. 5DPO Small-Size and Middle Size teams are mostly implemented in Object Pascal (Borland Delphi).

The RoboCup Rescue domain [2,3] includes six types of agents that may be controlled by each team: Fire Brigade agents; Police Force agents; Ambulance agents; and Control centers of three types (fire stations, police offices and ambulance bases).

Center agents are responsible for message routing and global tactical reasoning for each type of agent. These agents are configured initially with the team strategy and try to follow it during the rescue operation.

Our agents' low-level strategy is mainly the following. At the begin of the search and rescue operation, Police agents try to free "main routes" in order to enable ambulance agents and fire brigade agents to move freely between far locations. "Main routes" are defined using previously established map strategic points and computing the distances of the free tracks to the strategic points. These points include not only fire spots and civilian refuges but also map strategic crossings. At the middle/end of the search operation (configured on the team strategy), police forces are more concerned on freeing trapped agents and attending road clearance requests from other agents.

Ambulance strategy is fairly simple and is based on taking close civilian agents to refuges following known free paths. Close, severely injured (but not desperately injured) civilians are preferred for rescuing. A D* based algorithm is used in order to find the fastest free known paths for ambulance navigation in the map.

Fire combat strategy is more elaborated and is based on defining fire perimeters for known fires and on building neighbors. Fire brigades try to combat the fire using pre-defined collective plans for: attacking directly a fire, minimizing fire spread or containing the fire. For example, minimizing fire spreads is based on extinguishing fires in buildings that have a large number of neighbors and fire containing is based on minimizing the size of the fire perimeter. If fire is contained, fire brigades are used to search for buried civilians in order to maximize team global scoring.

3. High-Level Coordination Methodologies

After having our low-level code reasonably stable, our research is now focused on adapting coordination methodologies, developed for our RoboCup 2000 soccer simulation league team, to the rescue domain[2]. These coordination methodologies include:

- **Situation Based Strategic Positioning (SBSP).** This coordination mechanism [5,7,8] enables a team of agents to move in a coordinated way in a spatial domain, based on common a-priori tactical knowledge and simple environment knowledge [8].
- **Concept of Global Situation.** A situation is a high-level analysis of the search field that must be simple to perform by all agents, resulting in common global knowledge for all agents [8]. In soccer the situation is basically something like attack, defend, our goalie free kick, going from defense to attack, etc. In a search and rescue scenario it is something like avoiding fire spreading, attacking fire, etc. Although in the soccer simulated domain, the concept of situation is not of

[2] FC Portugal 2000, mainly due to its new coordination methodologies, was RoboCup European and World champion in 2000, scoring 180 goals in those competitions without conceding any goal.

primordial importance for the SBSP positioning system, in other domains like battlefield or rescue, situations are very important for positioning agents.

- **Definition of a Team Strategy for a Competition.** FC Portugal flexibility lies essentially on our formalization of what is strategy for a competition [5,8]. This strategy is composed by tactics with activation rules (based on statistical information of the performance of the team in executing the task). Tactics include several high-level parameters like the group mentality, level of risk taken, etc. and also several formations to be used in different game situations (fire attack, sustaining fire in a line, etc.).
- **COACH UNILANG – A Standard Language to Coach a (Robo)Soccer Team.** Coach Unilang [6] was the first high-level coaching language introduced in RoboCup. It enables to improve team coordination by letting a supervisor agent to define the team strategy and perform the tactical changes in the team during the execution of a cooperative task by a group of agents. In a search and rescue scenario, high level a-priori definition of the team strategy is essential to coordinate the team during the disaster. Coach Unilang with several high-level modifications will be used by our team to define the team strategy before the competition. This strategy will be followed by the center agents in order to coordinate the moving agents. Our coach for RoboCup Rescue is a simple application that performs off-line analysis of logfiles showing the team behavior, and decides the strategy for each rescue operation before the start of the competition.
- **ADVCOM – Intelligent Communication using a Communicated World State.** Intelligent communication mechanisms are crucial in RoboCup Soccer and Rescue due to the low-bandwidth available at these competitions. Our communication mechanism in the simulation league is based on agent's deciding the relevance of communicating a given piece of information by comparing their own world states with a world state constructed using only communication. Based on the differences between these two world states, agents decide which pieces of information to communicate [5,7].

Our research on team coordinating techniques is not limited to the RoboCup Soccer and Rescue domains and most of the methodologies developed for these domains are applicable to other domains in which spatial coordination is needed. These domains include battlefield scenarios, ecological simulations [24] and RoboCup robotic leagues.

4. Related Work

There are several teams developing agents with advanced learning and coordination capabilities for RoboCup Rescue Simulation. Paquet et al. [9] present a very good survey concerning the use of coordination methodologies in RoboCup Rescue. Several other teams present very interesting work on applying coordination methodologies to Rescue [10, 11, 14, 15, 16, 17]. Concerning the use of learning methodologies there are also several different approaches [10, 11, 12, 17, 21, 23].

ResQ Freiburg [11] deals with sequence of planning methods. The objective is built hierarchic commands that mean hierarchic behaviours. ResQ Freiburg [12] uses twofold strategy in platoons: reactive and cooperative behaviours. To preserve hierarchic levels, this strategy can be overridden by deliberative high-level decisions of the centre agents. The goal is to successfully coordinate teams of agents for the sake of the limitation of damage to people and buildings. The decision about the execution of actions is decomposed on the one hand into a reactive part by the platoon agents and on the other hand into a deliberative part by the centre agents. They use prediction methods instead of classical planning research. Use of hierarchical reinforcement learning [13]. The skill selection mechanism of platoon agents uses is an evaluation function for possible targets with respect to current state of the environment. This function is calculated based on prediction models described above which will be further extended to use hierarchical reinforcement learning. Centre agents decide skill execution in the long term by allocating groups of platoon agents to particular tasks. Their decision making is based on a module for state prediction and abstraction that generates the input for a novel multi-agent planner.

DAMAS Rescue team [10, 18] concentrates his attempt to extinguish buildings on fire. To solve it, an idea of a selective perception learning method to classify the best fire to extinguish was created. To choose the best fire zone to attack, agents are using two levels decisions making process – a global view and a specific view. Global view talks about the agents looking at groups of buildings on fire. Specific view makes use of more detailed information to choose which specific building to extinguish in the chosen fire zone. The collected data of environment simulation will compose a list of all buildings on fire. The correlation between utility and expected reward can be seen as an estimate of the capability to extinguish a given fire. Using perception technique [19], the aim is to learn how to coordinate agents to extinguish the more important fires in a given fire zone. In development of agents' plan, DAMAS Rescue team had used Jack Intelligent Agent programming language [20], decision tree and reinforcement learning [19]. During the simulation, the agents use the tree created offline to decide the best fire zone and the best building on fire to extinguish. This has the effect of reducing the state space of the reinforcement learning algorithm and thus facilitating the learning process.

Phoenix Rescue team [21] proposes a general agent paradigm and a specific agent paradigm for rescue simulation. Using symbolic and connectionist approach, agents will be able to acquire knowledge and to act in world simulation model. For learning, communication, knowledge and others key factors are divided and integrated in a general way regardless of problem domain. The learning process makes use of two agent paradigms: hierarchic and hybrid (deliberative/reactive). Others three modules: action control, knowledge acquisition and communication control. The knowledge is hierarchical from simple to complex. Simple knowledge types used in rescue domain include burning buildings, blockade roads, building with buried persons. Some complex knowledge are used in the rescue domain might be team formation, communication methods and crucial parameters but should not be limited to above types. Experimental test involving four programs make clear that knowledge improve performance. Agents with cognitive capabilities can perform better than reactive agents in this domain.

SOS team [17] makes efforts to create the best path-finding. Two path-finding modules are used to acquire the goal, Focused D* algorithm and Dijkstra algorithm. Focused D* is used on integrating search criteria into heuristic functions for heuristic search methods. In this method, a search function space is clustered into regions of equal size using Simulated Annealing, based on idea of Kohonen's SOM [22]. Therefore, Voronoi diagram is constructed from the cluster representatives and the regions extracted from the diagram are assigned to the agents for searching. In priority of actions, they are using Reinforcement Learning. Cooperation method in behaviour aspects, each agent has a class of predefined behaviours, so automatically flee perilous states.

RoboAkut [23] is concerned to achieve effectiveness in agents with inference mechanisms of and cooperative learning. Each agent is capable of deciding for itself when is no support from other agents. The agents make use of the sensory information they obtain to learn the state of the environment and consequently to decide on the actions to perform. In the routing module, the structural information provided to an agent includes the positions and neighbours of each building and road in the environment. A* search is carried out for finding a path from the source to destination. There is a limit on the depth of the search tree for safety. In learning module, twofold kinds of learning are used, Table Based Q-Learning and Neural Networks. Reinforcement Learning is used as the learning module by all team agents. Each agent learns from the results of the actions it does. Having several methods of reward, one method is Q-value. In dynamic environment with further unknown states, Feedforward is the best choice in emerging behaviour because is able to give more flexibility.

5. Conclusions and Future Research

Our team development is only in its beginning but the first results achieved are promising. Like in other RoboCup leagues, we believe that our high-level coordination methodologies may lead our team to achieve very good results in competitions, starting in our first participation in RoboCup Rescue[3]. Our Configurable Flexible Team Strategy and our Situation Based Strategic Positioning [5, 7, 8], now used by most of RoboCup Soccer Simulation teams seem to be a very promising coordination methodologies also for RoboCup Rescue. We plan to fully adapt, implement and correctly instantiate (for the search and rescue domain) these coordination methodologies in our FC Portugal team for RoboCup 2004 rescue competition, developing a very competitive team.

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