The Multi-team Formation Precursor of Teamwork

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Abstract. We formulate the multi-team formation (M-TF) domain-independent problem and describe a generic solution for the problem. We illustrate the M-TF preference relation component in the domain of a large-scale disaster response simulation environment. The M-TF problem is the precursor of teamwork that explicitly addresses the achievement of several short time period goals, where the work to achieve the complete set of goals overwhelms the working capacity of the team formation space (all teams formed from the finite set of available agents). Decisions regarding team formation are made by the agents considering their own probabilistic beliefs and utility preferences about the whole (known) set of goals to achieve. The RoboCupRescue simulated large-scale disaster domain is used to illustrate the design of the preference relation domain-specific M-TF component.

1 Introduction

Teamwork has emerged as the dominating coordination paradigm for multiple agents aiming to achieve goals within dynamic, uncertain and hostile environments [1]. The key precursor of teamwork is team formation, which is the process of how best to organize the agents into a collaborating team in order to achieve a specific goal [2].

The team formation process is usually triggered by a goal that overwhelms the individual (single agent) capability. Therefore, when faced with several overwhelming goals, the immediate response is to repetitively apply the team formation solution to each goal. As the number (and difficulty) of goals increase, also new sets of available agents are required to form new teams.

The continued demand for new teams, although theoretically admissible, becomes operationally infeasible within a resource-bounded environment. The mitigation of a large-scale disaster, caused either by a natural or a technological phenomenon (e.g. an earthquake or a terrorist incident), is such a resource-bounded environment where teamwork is the critical response to the disaster; several simultaneous goals call for the immediate response of multiple specialized teams.

There are no standards on how many resources are sufficient to mitigate a large-scale disaster and the general rule is to use as many resources as possible to reduce damages; more resources being required to rescue larger areas and harder

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disasters. This general rule cannot be used in earthquakes because fires occur simultaneously throughout cities and resources (fire brigades) are finite [3]. In order to use finite resources effectively, it is necessary to evaluate the multiple and simultaneous damages and the resources' ability to mitigate those damages.

The operational perspective of teamwork is that agents and goals are resource-bounded elements. The *agent availability* is the first boundary; the agent set is finite and each agent only belongs to a single team. The *time to goal* achievement is the second boundary; goals are to be achieved within pressing deadlines.

The resource-bounded perspective of teamwork is best understood while trying to mitigate a large-scale simulated disaster. The RoboCupRescue [4] is a simulation environment of large-scale disasters. It is a resource-bounded simulated context that brings forth a semi-optimal behavior planning problem with extremely complex constraints and having time-varying multiple goals [5].

The work described in this paper is highly impelled by the concrete difficulties we came across during the participation at the RoboCupRescue 2004 International Championship (with the 5Rings team [6]). Our agents were qualified for the competition semi-finals but, at the end, their competitiveness revealed insufficient to achieve an high ranked classification. It became clear that the weakness of our agents followed from a team formation lacuna. We lacked a situation evaluation under uncertainty mechanism and a decision making technique that accounted for several simultaneous achievement goals given a finite set of agents.

The resource-bounded perspective of teamwork, materialized through the experienced difficulties of RoboCupRescue, shaped our formulation of the multi-team formation (M-TF) problem.

We conceive the M-TF problem as the most general precursor of teamwork. The M-TF is defined as a domain-independent problem that explicitly accounts for both a global and a local rationality for teamwork (respectively, the preference relation, $\Psi\gamma$, component and the derogation function, X_G, component) and also explicitly considers the impact of simple futuristic causal relations (the expected achievement goal set, Λ_G, component) on the teamwork performance. In this paper we illustrate the design of the preference relation, $\Psi\gamma$, component in the RoboCupRescue domain.

The solution of the M-TF problem is a team formation decision. The major quest for the M-TF solution is to determine "which goal should an agent commit to". We formulate two basic strategies. Both strategies depart from the definition of a total order importance relation among goals; agents commit to goals as to minimize the cost of team formation and reformation. One strategy searches for the minimal global cost of commitments. The other strategy considers that higher importance goals "choose agents first"; it searches for several locally minimal cost commitments.

The M-TF problem formulation represents our initial contribution towards an agency (collective) enforcement of teamwork.

This paper is organized as follows. In Section 2, we define the M-TF problem and in Section 3 the general solution of the M-TF problem is described. The Section 4 characterizes a simulated domain (taken from RoboCupRescue) and in Section 5 that domain is used to illustrate the design of the M-TF preference relation component. The Section 6 summarizes our proposals and outlines the future work.