Planning Requirements for Hierarchical Coalitions in Disaster Relief Domains

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Abstract

Coalitions are organisations whose members combine abilities and knowledge to carry out mutual purposes. Rather than to be composed by a team of equals, coalitions generally require a hierarchical structure of command and control where agents take different and complementary kinds of decisions at each level. This paper presents the development of a hierarchical coalition support system, considering its use in disaster relief operations. Based on this application, we discuss the planning requirements of the system and how they will be integrated to provide important functionalities to the coalition members.

1. Introduction

Research in coalition support systems intends to develop a set of technology that provides ways to different and probably disperse humans and/or software agents working together, sharing competencies and information. Currently this technology is mainly been applied in a military context to enable interoperability between heterogeneous components [1] and to develop tools that support the processes of command and control during missions [2].

Disaster relief domain is another area that can make use of coalition support systems. Actually this domain encloses several issues that are associated with coalition systems. First the nature of the problem demands a set of different abilities (fire brigades, paramedical body, police, rescue teams, etc) to accomplish different tasks (extinguish fire, find buried people, take care of injured civilians, control evacuations and so on). Second agents have to act in a collaborative way, sharing information and abilities. Third the anywhere/anytime feature of disasters requires that coalitions be rapidly created and flexibly changed as circumstances alter. At last, there is the problem of integrating the heterogeneous systems belonging to multiple organisations (hospitals, fire centres, etc.) with distinct doctrines and rules.

I-Rescue [3] is a research programme, anchored in the I-X technology [4], that aims to develop knowledge-based tools to disaster relief domains. *FireGrid* (coordination of agents during indoors disaster operations) and *e-Response* (stabilisation and support of response teams for environmental disasters) are examples of initial projects associated to I-Rescue. One of the aspects of this programme, which is discussed in this paper, involves the definition of a coalition hierarchical structure of command and control and the investigation of planning processes through its levels. Our intention is to group agents in complementary levels of decision so that the system can provide customised facilities in accordance with the planning activities performed into each level.

The remainder of this document is structured as follows: section 2 gives an overview of our ongoing application, summarising the system architecture, technology that we are using and current tools anchored in this technology. Section 3 presents the coalition planning requirements and directions of how they will be integrated in the current application. Finally section 4 discusses some conclusions and future works.

2. Supporting Hierarchical Coalitions

Our application considers three levels of decision-making (strategic, operational and tactical) in which agents perform different kinds of tasks. Strategic agents carry out activities of analysis and directions, building plans in a high-level of granularity. Operational agents account for activities of synthesis and control, refining the plans produced in the upper level via processes as resource scheduling and load balancing. Tactical agents are involved with reactive activities and task execution. This hierarchical arrangement is a common practice in military models of command and control [5] and consistent with knowledge engineering work[1].

Agents are, in fact, I-X Process Panel (IP^2) [6] instances that assist users in carrying out their activities while integrate them in a collaborative hierarchical structure of planning and execution. IP^2 utilises the <I-N-C-A> ontology [7] to represent plans and to share knowledge. The figure below (Figure 1) illustrates the planning process model.

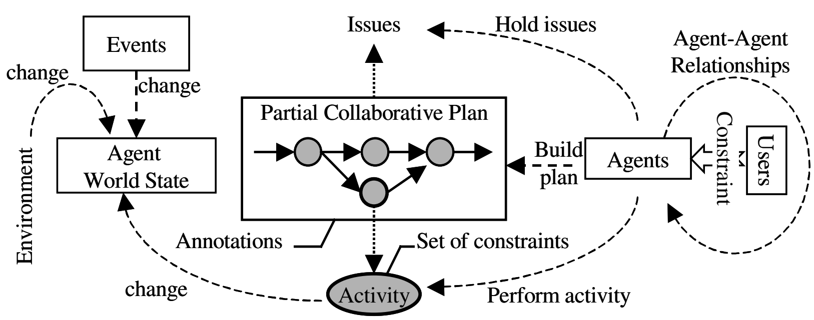

Figure 1 Planning process overview

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[1] KADS methodology, for example, separates the different "task types" (diagnosis, interpretation, monitoring, etc.) into three classes: analysis, synthesis and modification tasks.

Each plan is made up of a set of *Issues* and *Nodes*. Issues represent potential requirements that need to be considered at sometime. Nodes represent activities in the planning process that may have parts called sub-nodes making up a hierarchical description of plans. Nodes are related by a set of detailed *Constraints* of diverse kinds such as temporal, ordering, priority and so on. *Annotations* add complementary human-centric and rationale information to the plan.

Agents are organised in levels using the I-Space tool (part of IP^2), which manages hierarchical relationships of a specific agent to others agents and external services. Currently all IP^2 are acting as a workflow, reporting and messaging "catch all" for their users. They are been used to support an user or collaborative users in selecting and carrying out processes and creating or modifying process products. Our current intention is to expand its capability so that the panels also support the joint activities of planning and execution.

3. Planning and their Requirements

The hierarchical coalition organization implies in some requirements to the planning and execution activities, which are also influenced by the features of disaster relief domains. This section focus on the planning aspects that we need to consider in our model and shows how they can be represented using the <I-N-C-A> ontology and manipulated via IP^2.

3.1 Mixed-Initiative Planning

Mixed-initiative planning has several advantages: intensifies the user control and involvement, permits user interaction during the whole decision process so that users are able to understand why ways were chosen or avoided, and removes the premise of complete and bug-free knowledge. Actually this style of planning is suitable in critical domains, such as disaster relief domains, where decisions involve human lives and users will not ascribe a complete autonomy to agents so that they only take decisions by themselves.

<I-N-C-A> represents each plan as a set of constraints on the space of all possible plans of a domain. During the generation and manipulation of plans, an IP^2 checks and maintains the set of constraints related to this plan. IP^2 can also generate annotations that denote problems or motives to reconsider some activity or issue. Users act by adding or relaxing the plan's constraints and this is the way that they will influence the planning process in a mixed-initiative fashion.

3.2 Joint Commitments

In a hierarchical coalition structure, superior agents generate activities that are delegated to subordinate agents, which need to commit on the performance of such activities. Subordinate agents have to follow their commitments because they are not able to evaluate how their decisions affect the coalition's long-term goals.

IP[2] defines, using <I-N-C-A>, delegation and report messages to support the processes of commitment. Basically the receiver agents consider the delegated messages, making a commitment of reporting their progress, success or failure. This commitment supports the process of prediction (via activities' progresses) and problem detection (via a failure report) in the global plan. Furthermore report messages can also hold any information or event that has influence on this activity. Details and syntax of the messages can be found in [4].

3.3 World State (Agents and Environment Descriptions)

Agents can be described by their abilities of carrying out activities and constraints on such abilities. These descriptions will support the tasks of localising the most appropriate agents to specific activities during the delegation process. In order, while strategic agents only need of high-level descriptions of their subordinates (operational agents), operational agents need of a more detailed knowledge of how their subordinates execute the activities. This knowledge can support the tasks of compounding new capabilities through the interoperation and union of others existent capabilities, verifying capabilities properties and monitoring the execution of tasks performed by agents.

The system codifies each of these agents as a set of pattern-value pairs (constraints). An IP[2] pattern is, in general, a n-tuple, currently though we are using two elements in the patterns: the first to keep the attribute and the second to keep the object ID. So we can represent all subknowledge as (<attribute> <object>= <value>). The environment is described as facts in the same format, and the system deals with both agents and environment features as states of world. However, as the rescue domains are dynamic, joint agents often encounter differing, incomplete and possibly inconsistent views of the environment and (mental) state of other agents. So we are extending the patterns by considering a "time element" (<attribute> <object> <time>= <value>) that support the agents in reasoning only on the most recent facts.

3.4 Temporal Model

As agents in the strategic level do not have detailed information about the duration of activities execution, they use a qualitative model of time (e.g. $task_1$ *after* $task_2$) to synchronize such activities in a high-level plan. On the other hand, while the use of a qualitative time model by the strategic level is necessary to avoid that its agents take decisions about things that they do not care about (using the least commitment principle), the operational level can use a quantitative model of time (e.g. $task_1$ *duration* 29min) to improve decisions. A quantitative model of time enables resource allocation processes to increase the amount of concurrent acting, avoiding that agents wait a long time to receive tasks. As agents have no control on the duration of some tasks in disaster domains (e.g. extinguishing fires, finding buried people, etc.), duration values are usually estimations that can be based on past-cases and capacities of performing agents. Thus each operational agent needs to have an appropriate description of its subordinate agents.

3.5 Conflict Resolution

Generally conflicts can be avoided by synchronising dependent activities. For example, if the paths to a fire are blocked, "extinguish fire" activity depends on the "clean path" activity. So we can add the constraint (extinguish *after* clean). However as agents are each building their own plans, some of them can produce effects that disrupt the activities of others agents. In our current implementation each level accounts for delegating synchronised activities for its subordinate agents. In addition we are implementing mechanisms that generate a set of constraints that must hold within the interval of time that subplans are been built or executed.

4. Conclusion and Directions

Our current application provides ways to support hierarchical coalition via agents (panels) that assists users in carrying out their joint activities, sharing knowledge and abilities. Our framework is anchored in a general-purpose constraint-based representation that shows to be a natural way to model the elements related to plans. Our aim is to expand the agents abilities so that they support the collaborative activities of planning and execution. Each hierarchical level will account for specific activities of the plan and their agents will be customised (via the IP^2 open interface) to provide support to such activities.

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