Technical Report

Mixed Initiative Multi-agent Planning: A Simple Demonstration

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August 7, 1997

ARPA-RL/O-Plan/TR/34 Version 1

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1 Introduction

This report describes the A-2 deliverable for the O-Plan project. We have created a Web-based demonstration of our ideas on mixed initiative multi-agent planning, based on a Course of Action / Elements of Evaluation comparison matrix. We are using a general-purpose logistics and crisis operations domain which is an extension of our earlier logistics-related domains. The intention is for this demonstration to be the basis for both our A-3 and A-4 deliverables and our TIEs with Rochester (TRAINS) and USC/ISI (EXPECT).

2 User Roles and the COA Comparison Matrix

The overall concept for our demonstrations of O-Plan acting in a mixed initiative multi-agent environment is to have humans and systems working together in given roles to notionally populate a Course of Action (COA) / Elements of Evaluation comparison matrix (see Figure 1). The columns of this matrix are alternative options being explored as a potential solution to a (possibly underspecified) problem and the rows are evaluations of the solution being considered. The idea is that the requirements, assumptions and constraints are all refined concurrently using the elements of evaluation (EEs).

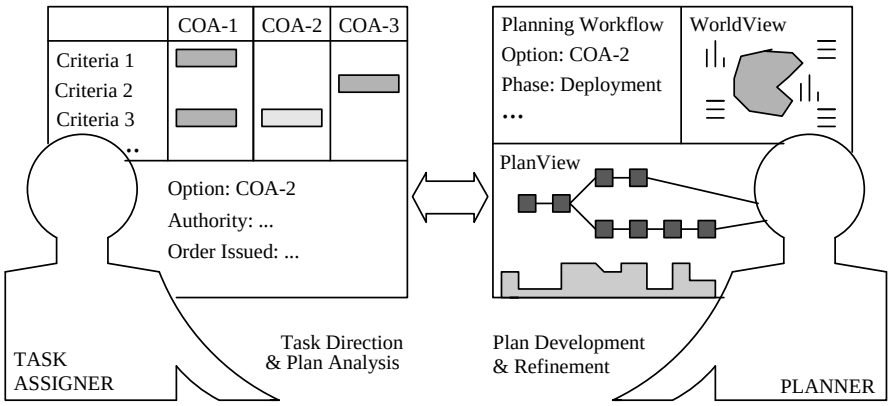

Figure 1: Communication between the Task Assigner and the Planner

We are exploring the links between key user roles in the planning process and automated planning support aids [1]. Research is exploring a planning workflow control model using:

- a shared model of mixed initiative planning as "mutually constraining the space of behaviour";
- the <I-N-OVA> constraint model of activity as the basis for communication;
- explicit management between agents of the tasks and options being considered;
- agent agendas and agenda issue handlers;
- explicit provision of authority for an agent to perform its functions.

Agents maintain their own perspective of their part in the task to hand, while cooperating with other agents who may perform parts of the task.

As shown in Figure 1, we envisage two human agents, called the Task Assigner and the Planner, working together to explore possible solutions to a problem and making use of automated planning aids to do this. Figure 2 shows how the two human agents work together to populate the COA comparison matrix. The Task Assigner sets the requirements for a particular Course of Action (i.e. what top level tasks must be performed) and selects appropriate evaluation criteria (elements of evaluation) for the resulting plans. The Planner agent acts to refine the resulting plans by adding further constraints and splitting plans to explore two or more possible options for the same COA requirements.

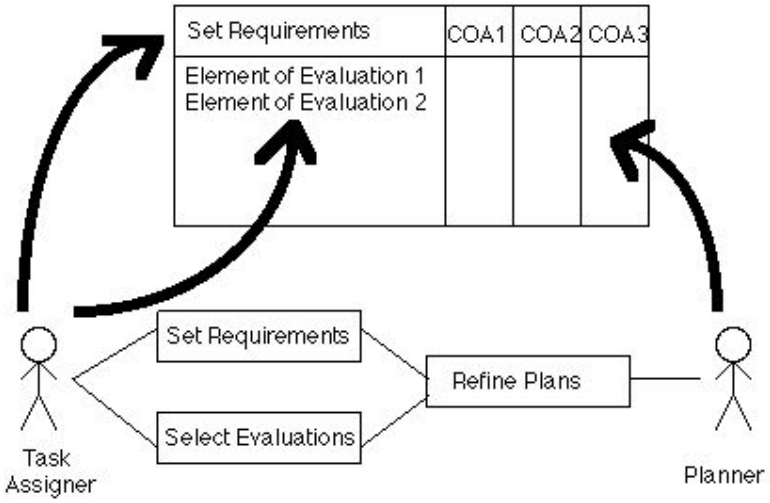

Figure 2: Roles of the Task Assigner and the Planner

Our TIEs with Rochester and USC/ISI are intended to fit into this picture of things. We see Rochester (TRAINS) as providing most of the "task assignment" level to the framework. This sets the objectives, defines the assumptions on the initial situation, sets up constraints on how the user wishes to create a solution, and so on. The work with USC/ISI (EXPECT) is meant to offer an insight into (for example) how users might evaluation alternative plans and what measures they will use to make the comparisons.

As our A-2 deliverable, we have created a simple Web-based demonstration which shows most aspects of the abstract framework described here. The demonstration is available at `http://www.aiai.ed.ac.uk/cgi-bin/oplan/web-demo/gpdt.cgi`. The user is initially given a blank COA comparison matrix which is populated by the user and O-Plan during the course of a session (Figure 3). The user acts in the role of the Task Assigner agent, setting the tasking level requirements for a Course of Action (Figure 4) and selecting elements of evaluation to include in the matrix.

The COA matrix is an abstract underlying notion and may not appear in a user interface for a completed system. However, it is useful in this demonstration to show our ideas about what is being created and refined as mixed initiative problem solving takes place.

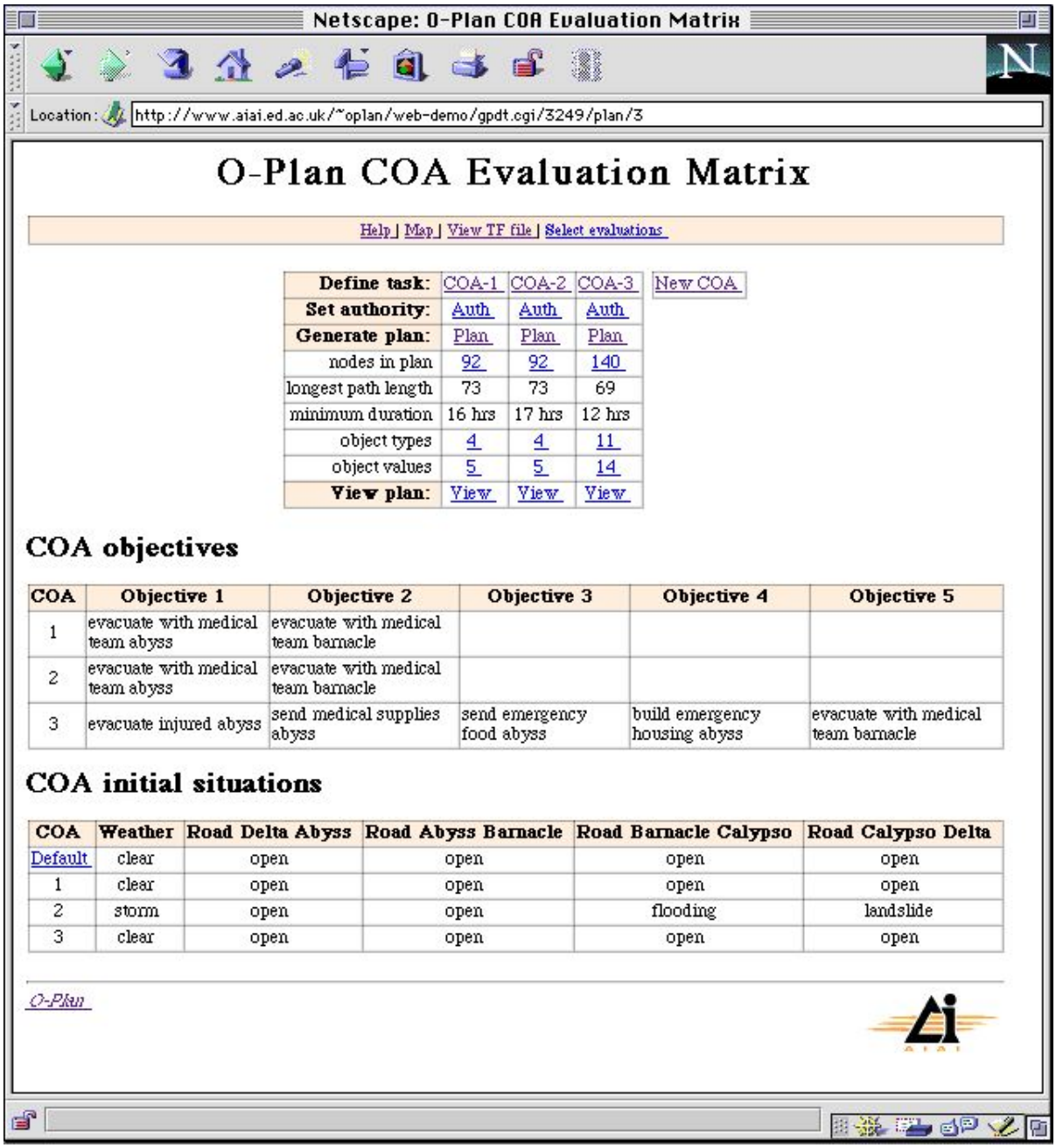

Figure 3: The Course of Action Evaluation Matrix

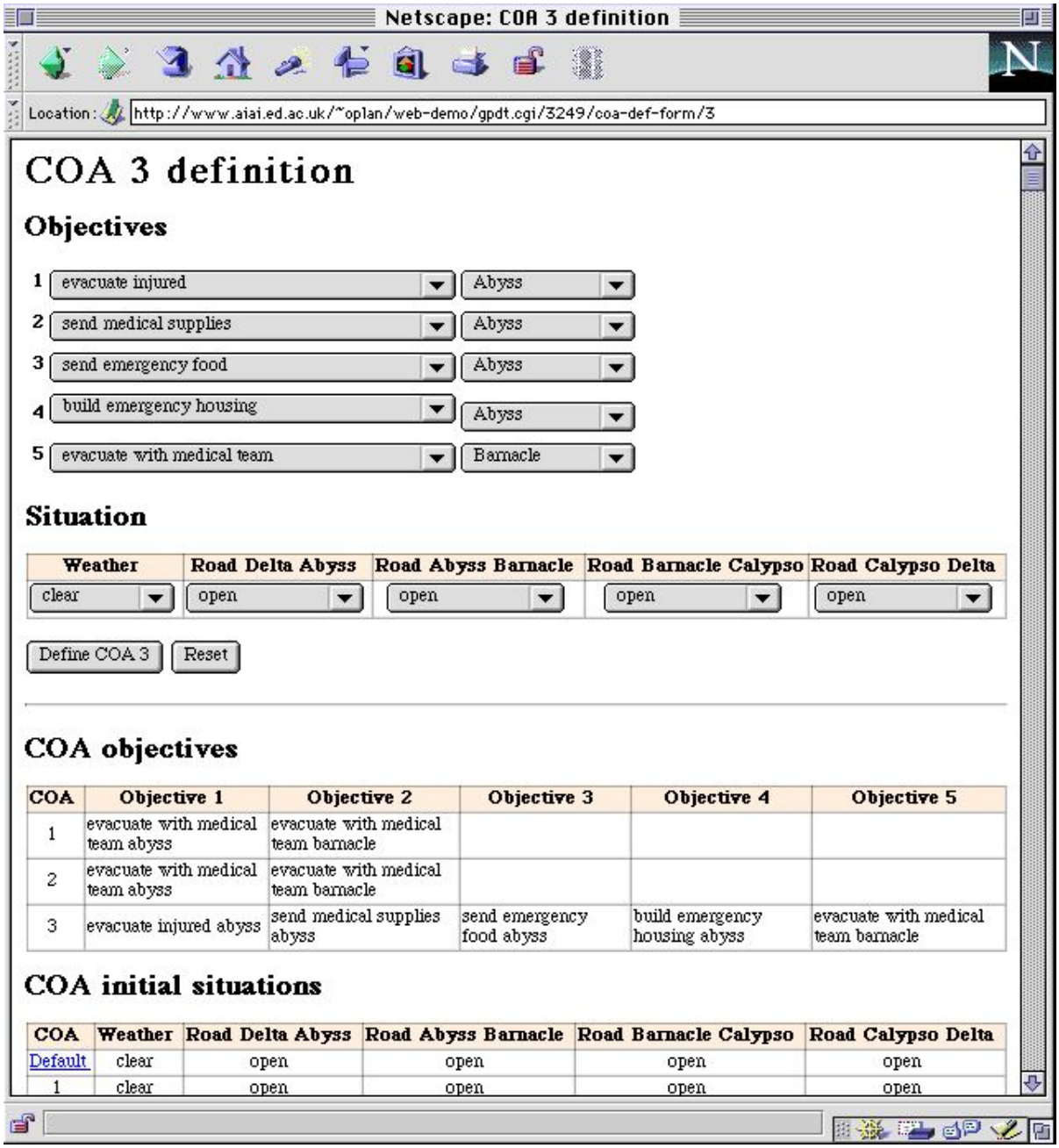

Figure 4: Defining the Requirements for a Course of Action

3 The Crisis Operations Domain

We have used a crisis operations domain based on the Pacifica scenarios that we call "Go Places and Do Things" (GPDT). This is a three level domain model which closely follows what we observe in large real domain models. The top level is mostly about setting objectives (i.e. COA requirements). The second level is the real planning level and where technological interactions, such as allocating limited resources, need to be resolved. The third level is needed to add detail to the skeleton plans that have been selected.

This domain is a natural extension of our earlier work in the Pacifica NEO domain [2]. In the earlier work, people are evacuated from a small island using trucks and helicopters. In the new domain, the main goal is to avert a developing crisis in one of the cities on the island, using various vehicles, pieces of equipment and specialist teams. In the crisis domain, unlike previous Pacifica scenarios, the tasks to be performed are complex and may involve plans consisting of hundreds of individual actions.

This domain has been chosen for our current work to demonstrate that O-Plan is sufficiently powerful to be able to cope with these complicated logistical problems and also to provide the O-Plan team with a problem domain which is general enough to allow expansion and experimentation as our ideas develop.

3.1 The Scenario

The action takes place somewhere in a network of cities, currently on the island of Pacifica (see Figure 5). A number of crisis situations can arise in the cities and on the roads joining them, such as power stations becoming inoperative or people needing medical treatment. The goal of the commander (i.e. the Task Assigner agent) is to respond effectively to the situation so that the immediate crisis situation is dealt with and appropriate repairs are made to restore the status quo.

3.2 World Description

The following types of objects exist in this domain:

Cities: these can contain other objects, such as teams, people and equipment.

Roads: these connect some of the cities. They may become blocked to certain classes of vehicle due to weather conditions or landslides. Some may be permanently blocked to certain classes of vehicle (e.g. mud tracks).

Vehicles: these are used to carry equipment, teams and people between cities. There are various types of vehicle which have very different capabilities, such as fast air vehicles of low carrying capacity and slow ground transports capable of carrying large pieces of equipment.

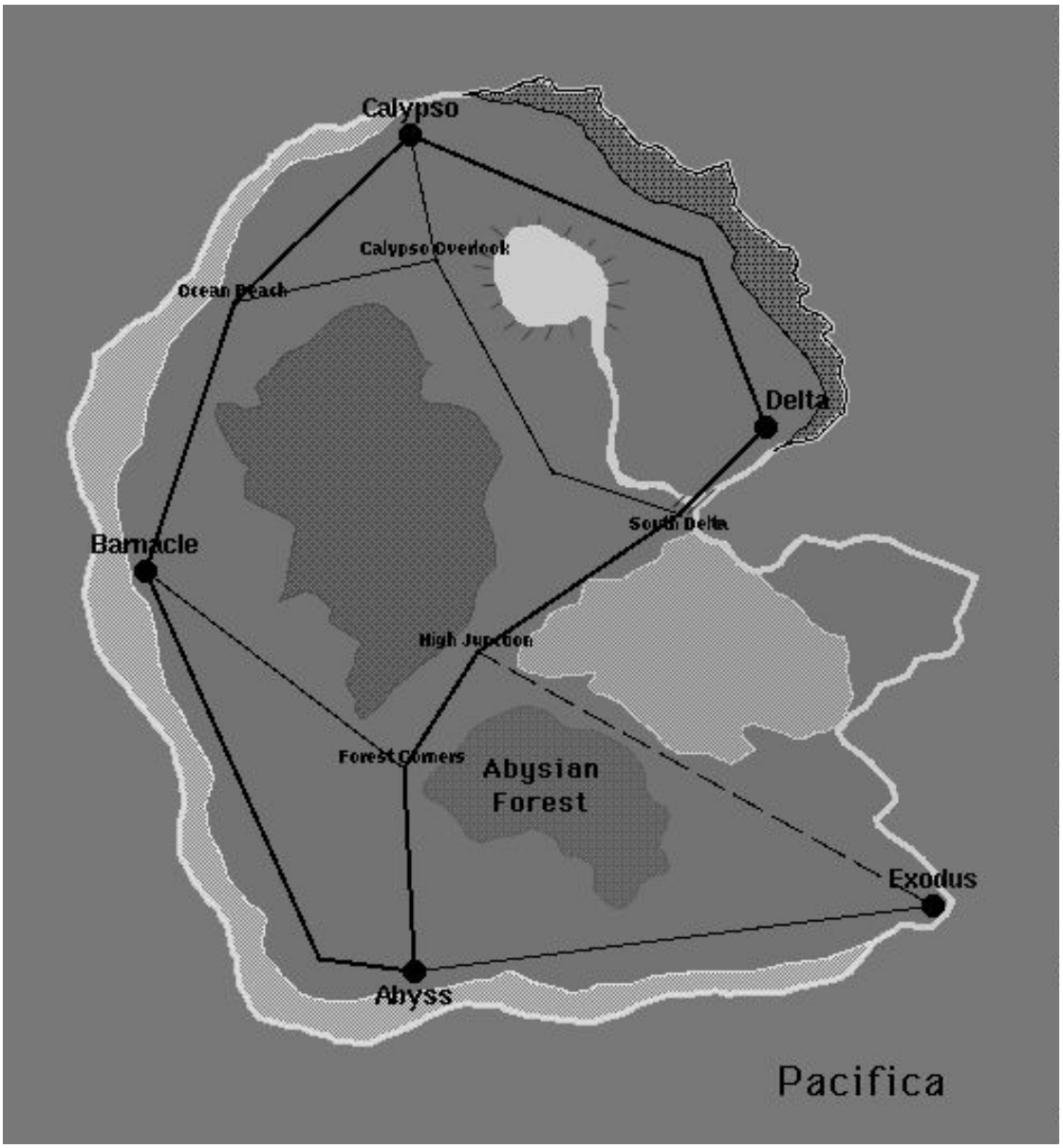

Figure 5: The Island of Pacifica

Equipment: there are various pieces of specialist equipment located in the network of cities. These are needed to perform certain tasks, such as repairs at a power station or emergency medical treatment.

Teams: there are also various specialist teams of people located in the cities. These teams perform specialist tasks, such as fast evacuation or building emergency housing.

People: people are located at cities and may need medical treatment or evacuation. As a simplification, we treat people as a single entity to be treated or moved around, rather than counting a specific number.

Weather: the weather may restrict the options available to the planner, such as not allowing helicopters to fly in thunderstorms.

The world state can be described by giving the locations and contents of the vehicles, the locations of the people, teams and pieces of equipment, and the status of the roads, people and weather.

3.3 Actions and Plans

In this domain, the teams, equipment and people can be moved around using a TRANSPORT action at Level 2:

> TRANSPORT cargo ITEM using VEHICLE from CITY to CITY
> where ITEM is an object of type team, vehicle, equipment or people.

The result of the action is that the cargo moves from the source to the destination. This Level 2 schema will expand to give a number of individual actions at Level 3. For example, "TRANSPORT cargo MT1 using GT1 from Abyss to Barnacle" might expand to the following sequence: fuel GT1 at Delta, drive GT1 to Abyss, load MT1 at Abyss, drive GT2 to Barnacle and unload MT1 at Barnacle.

Other actions in the domain are dependent on the specific example chosen, but will typically be expansion-oriented plans with up to 200 actions at the lowest level. Typical examples are:

- Repair a turbine at a crucial power station.
- Give emergency medical treatment to people exposed to toxic fumes.
- Repair a bridge which has been broken in a storm.
- Repair the hydraulic system on one of the aircraft.
- Build emergency housing for refugees.
- Perform emergency operations to make the area safe for a repair team.
- Evacuate the population of one of the cities.

Typically, an entire plan will consist of a number of TRANSPORT operations to bring the necessary teams and equipment together, followed by the main tasks. The TRANSPORT operations and main tasks may overlap, as in the example where it is necessary to send someone to perform emergency operations while the main equipment and teams are arriving using slower vehicles of high carrying capacity.

3.4 Implementation Status

The current Task Formalism (TF) file implements the crisis operations domain for the island of Pacifica, using 12 top level tasks and four cities (Abyss, Barnacle, Calypso and Delta). A Course of Action consisting of 5 tasks at the top level expands to give approximately 30 actions at the second level and 150 tasks at the third level. The exact numbers will depend on the particular Level 1 tasks selected for the Course of Action.

There are a number of deficiencies in the current TF file which we aim to address in future versions:

- The status of the roads is not currently taken into account, even though it is possible to change this from the "COA N definition" screen.
- The transportation is done in a very simple way, without doing any route planning. Also, all trips by a given class of vehicle take the same amount of time no matter what the distance is.
- At the end of a COA, the equipment, teams and vehicles are scattered around the map. It would be useful to be able to "bring everything home" after the main task of the COA are complete.
- The weather status is taken into account by not allowing helicopters to fly in storms. However, the way in which this is done means that in non-stormy weather the planner will try to construct the entire plan using helicopters where it can, before considering the use of ground transports for some of these missions. This means that the generated plans (which are the first ones that O-Plan finds) may not be as parallel as they can be.

4 Future Work

The current demonstration has some limitations, and we plan to address these in the A-3 deliverable. The most important item to be addressed is to provide the Planner agent with the ability to impose constraints on plans and set up options to explore two or more plans which satisfy the same Course of Action requirements. We also intend to enable use of the "authority to plan" facility provided by O-Plan version 3.1, improve the treatment of the domain and give a demonstration of how plans may be specified, visualised and refined via a graphical Java-based process editor.

References

[1] Tate, A., Mixed Initiative Interaction in O-Plan, Proceedings of AAAI Spring 1997 Symposium on Computational Models for Mixed Initiative Interaction, Stanford University, March 1997.

[2] Reece, G.A., Tate, A., Brown, D. and Hoffman, M., The PRECiS Environment, Paper presented at the ARPA-RL Planning Initiative Workshop at AAAI-93, Washington D.C., July 1993. Also available as University of Edinburgh, Artificial Intelligence Applications Institute Technical Report AIAI-TR-140.