RescueModel: A Simulation Framework for the Exploration of Agent-Environment and Agent-Agent Interactions in Team Situations

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ABSTRACT: Explicit representation of co-ordination structures within groups [1] is required to address technology base issues in implementing dynamic team structures and co-ordinated team behaviour for computer generated entities in simulation and simulators. Fidelity, representation, architecture of the environment, and the complexity of entity tasks are issues to be considered. This paper describes a project that will bring together the environmental richness found usually in large scale military operations research simulations with the architectural richness of agent models found usually in universities. The basic simulation architecture (RescueModel) will be based on the BattleModel framework, which allows for the integration of models of systems, human operators, and visualization systems [2]. It allows for integration of multiple models from different sources. Proposed applications of RescueModel include search and rescue and disaster response studies. The current scenario being developed is for large scale bush fires and fighting in the Australian environment, an area currently studied in human decision making and human-in-the-loop (H-I-L) simulation [3], and complements current work elsewhere on a new simulator for RoboCup-Rescue [4]. Of particular interest to the broader simulation community will be the results of studies of teamwork, in the assignment and reassignment of agents, agent environment interaction and specification, and collaboration and co-ordination in heterogeneous teams.

1. Introduction

Agents by their very nature are embedded systems, and interact with their environment and more interestingly with each other through the environment. Environmental fidelity has been a secondary goal in agent architecture testbeds such as TileWorld [5] and its successors. For instance, the basic TileWorld consist of a Cartesian grid containing obstacles with entities appearing and disappearing. Few agent systems have attempted to achieve higher degrees of environmental fidelity. A notable example is the Phoenix fire fighting system [6]. Improved environmental fidelity is a first step towards making agent systems more applicable to the real world.

The BattleModel architecture [2] was developed as a tool to support operational studies. It can incorporate high fidelity models of physical systems, and is used with agents to model rational entity reasoning. Current agent architectures have difficulty representing teaming and co-ordination within dynamic groups in situated environments. [7].

RescueModel is currently being developed for the exploration of social issues in agent oriented systems. This testbed has increased semantic and environmental fidelity relative to existing computer science testbeds like TileWorld but has reduced complexity compared to the models currently used by military simulations. The modelling framework is inspired by BattleModel but is:

- populated with adequate environment complexity to study situated social semantics and engineering,
- is architecturally isomorphic to real world systems,
- and has lower resolution models of the physical world (e.g. weather, atmosphere) as fidelity is not germane to the focus of the studies.

The RescueModel framework is general enough to be the basis for exploring important issues in computer science like models of distributed and heterogeneous agent collaboration and co-operation, roles, and models and tradeoffs for deliberation, commitment, and reactivity. It can contribute to the important goal of increasing the believability of computer generated forces in simulations [8-10]. The effect of environmental and domain characteristics on aspects of agent systems can be examined.
Important aspects of RescueModel either in place or to be developed include three-dimensional visualisation from the perspective of each agent, the ability to collect and analyse large amounts of data, and the ability to deal with appropriate level of complexity in a situation. The system is being built to further joint research with the simulation and agent architecture communities in a complementary manner to current RoboCup-Rescue proposals in the RoboCup community [4].

2. Agents and Environments

The actions an agent can take depend on the representation, complexity and fidelity of the environment it is embedded in. Indeed agents are situated in their environment and interact with other agents through it. The scientific questions one can explore are constrained by environmental fidelity and the manner of representation.

Many real world environments can be modelled as a heterogeneous environment containing different sorts of agents, and their inter-dependencies on joint goals. Important aspects include distractions to current goals that could have serious implications for the long term if left ignored. There are issues to do with the heterogeneity of agents, their roles, and the mapping between them. Issues arise with resource representation and the dynamic aggregation of resources, and also the possibility of multiple roles for agents and conflicting tasks. There are issues to do with models and tradeoffs in the areas of deliberation, commitment, and reactivity. There is a need to consider appropriate levels of complexity in a situation. For instance this could include conflicting actions and plans at varying levels of granularity, multiple types of agents, natural co-operation, and conflict between group and individual goals. There is also an issue of dynamic role allocation/re-allocation for team members. As agents are embedded systems, the level of analysis researchers can take to these issues is dependent on the environmental fidelity.

2.1 Fire Scenarios as a Rich Unclassified Real World Environment

Real world human decisions are sometimes made within short term time scales and highly dynamic environments. One application area with these features is search and rescue (SAR) within the context of natural disaster. This is an area currently being explored by the Robocup-Rescue project. RescueModel is designed to be architecturally similar to the Robocup-Rescue server.

Earthquake scenarios are being explored in Robocup-Rescue. However due to the availability of local expertise and experience in fire modelling, a decision has been made to explore bush fire scenarios using RescueModel. There is extensive scenario data for major fire disasters that can be used to put the studies in a social context.

Fire has many features that are of interest to agent modelling. The phenomenon is highly dynamic and life threatening. It is quick – a front can move as fast as vehicles over rough terrain. The front can jump lines of defence and appear long distances behind the line, leading to issues for dynamic fire teaming and tactics. Fire is subject to sudden unforseen changes, and fire units on the ground may have incomplete or inaccurate knowledge of the situation, leading to co-ordination and communication problems. Fire fighting requires co-ordinated teamwork between air and ground units.

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Logistical issues can also be investigated in fires. Examples include disabling bridges to reroute traffic, or lofting firebrands over large bodies of water to remote but populated islands that can only be reached by ferry or aircraft.

2.2 Previous Fire Modelling Systems

There are a number of fire modelling systems currently in existence. They include the Experimental Knowledge Systems Laboratory’s Phoenix system [6] for fire fighting in Yellowstone National Park. This system uses LISF for agent reasoning, and an automata-like fire spread algorithm. Latrobe University’s networked FireChief program has been used by DSTO’s Information Technology Division to study H-I-L command and control issues [3]. FarSite is a stand-alone fire growth simulation model for Windows that incorporates fire spotting [12]. CSIRO has SiroFire [13]. It is a physical model of fire perimeter spread, but not a fire fighting model.

The main drawback to most of these approaches is that the representation of the environment is not accessible to agents. However some aspects of each approach can be incorporated into RescueModel. For instance, CSIRO’s SiroFire simulator is being integrated as a physical model. However in SiroFire the cultural features like roads, tracks and railways, and certain natural features such as rivers and creeks are displayed but not used in calculating the fire spread. If researchers are interested in collaboration and commitment studies in the context of fire fighting tactics for instance, these features become centrally important. Equally important is three-dimensional visualisation from the point of view of each agent. Thus a polymorphic representation of agent friendly features is required. In other words, there is a need for a representation containing polygon information for scene rendering, and also feature labels which agents can reason about.

3. An Example Fire Scenario

To identify important agent-related issues for RescueModel it is useful to define a fire scenario and the elements in it that might affect an agent’s design and its decisions. Although this description is fictional, the features are drawn from real fires and events. The relevant players and components to this scenario are illustrated in Figure 1. Firstly, they include teams of agents such as fire fighters, and their associated platforms like fire trucks, helicopters, and different types of aircraft. Then there are the civilians who need to be protected and rescued. Civilians could also volunteer to help. Secondly, there are the physical models of the terrain, lakes and rivers, atmosphere, vegetation, and fire spread. Thirdly there are the cultural features like roads, houses, and bridges. Finally, there are measures of effectiveness and the tactics that are being investigated or assessed.

4. RescueModel Requirements

Teams are important in modelling organisational systems [14-16]. By assigning agents roles in teams there is a decrease in computation required for co-ordination and joint behaviours. A team may have subteams, and this structuring limits both the decision scope and the information required to make the decisions, facilitating computational performance. An explicit model of teamwork embedded in RescueModel would assist in reuse for other problem domains, where a team capability is required. Some teamed agent issues implicit in the above scenario include:

4.1 Dynamic assignment and reassignment of agents in fire teams.

The scenario raises the implications of changes in roles brought on by additions, reassignments, or losses of team members during execution of current joint intentions. Dynamic teaming might occur when fire teams split off to put out spot fires igniting behind the main front, or when civilians offer to help. Team resizing and role re-allocations occur either via an official chain of command or spontaneously. Then the teams might join back up again, or one might go off to join another team. An issue to be considered is long term goals and interests versus short term ones. It would be possible to examine issues like how long a temporary team change can be maintained before a long term goal suffers, and the ideal time split to facilitate both goals in terms of some measure of effectiveness. RescueModel could also be used to examine the ramifications of adopting Tidhar’s teamed approach presented in [17] versus Agent Oriented Software’s Simple Teams [18].

4.2 The effect of environmental and domain characteristics on decision making in teamed agent systems.

An issue that can be explored is the effect of environment change rate on decision quality versus timeliness. For instance, given a set of reasoning strategies the implications of speeding up the world change rate on a measure of effectiveness could be examined. Other possibilities include investigating the effect of assigning increasingly inaccurate or conflicting sensor information about the environment on agent decisions.

4.3 Different strategies for coordination in heterogeneous air and ground teams.

Grinton [19] has studied various commitment strategies in a dynamic TileWorld-like environment. It would be interesting to explore different strategies. On a separate note, another interesting area is whether Grinton’s results would generalise to more complicated environments.
After months of drought, high temperatures, and uncleared vegetation build up over the last few years, the region is set for a fire disaster. A blocking high pressure system has stationed itself off the east coast carrying strong, hot, and dry winds from the northwest. A strong cold front is imminent from the west. A series of fires might break out simultaneously or they might occur consecutively after each other. Fanned by the winds, they begin spreading to the south-east. Their initial location is in parks well away from residential areas, but they have the potential to spread to become life threatening. There are multiple fires, widely spread, but they are still small.

Multiple smoke columns and infra-red fire spots are detected by reconnaissance aircraft on morning patrol, and ground fire units are dispatched by the fire chief to these. Due to limited resources, a decision is made to split the available forces up into a number of task groups. Single air units are assigned to cover multiple ground groups as air resources are scarce. Helicopter borne smoke jumpers are called in to access the remote forested mountainous areas, unreachable by the vehicles.

The fire fighters have reached the affected areas. By now, the fires have taken up their usual elliptical shape and are a few kilometres long, on a front of a few hundred metres. The fires are now burning into heavy eucalypt areas. At this stage, smouldering strips of eucalypt are lofted up to 30 kilometres away creating multiple spot fires downwind. A decision is taken to pull a sizeable force off the main front to deal with these outbreaks.

Due to the strong winds, the suppression attempts are not going well. The spot fires are themselves growing and causing more spotting. These must be dealt with as a priority since they are now close to residential areas. Reinforcements are requested. The fire chief makes a decision to divert resources from one of the other main task groups to this area. However it will take at least an hour to get there and deploy, and that understaffed fire might become uncontrollable if conditions change.

The temperature has rocketed to over 30 degrees Celsius, with a forecast top of 43 in the afternoon. Although the main front has been controlled through a combination of air retardant drops and back burning, the expanding spot fires are still going. To add to the worries, a major bridge is currently impassable, causing logistical nightmares.

At this stage the cold front from the west has reached the area (see Figure 2). One of the main fires is still going, with a length of 10 kilometres on a kilometre wide front. As the westerly hits, the eastern flank of this fire becomes one huge front, threatening the units stationed there, and also nearby residential areas. Little rain is associated with the cold front.

The fire chief decides to withdraw most of the fire fighters from the bush and task them with protecting the suburbs and to evacuate some residents.

As the fire reaches the residential outskirts, lofted fire embers skip across the bay via spotting to the built up areas on the other side, but the connecting bay bridge is still unavailable.
Agents are situated in a virtual physical world and there are representational issues for this environment. They include how an agent divides the world up into components which can be reasoned about, and how the relations between these components are determined, based on the currently assigned role. There is the problem of making these relations agent friendly so agents can reason about them to achieve meaningful role-related actions.

4.4 Resource Aggregation

Then there is a question of resource aggregation. There can be different levels and types of aggregation for the world for both the environment and embedded agents.

4.4.1 Aggregation in the Environment

For instance, a forest could be represented by individual trees with specific locations and logical extents. This representation can increase the fidelity of agent line-of-sight calculations, and vehicle terrain interactions. Then again, trees might be defined through a probabilistic map over a certain spatial extent, so there is no notion of individual tree. Agent reasoning depends on the level of representation.

4.4.2 Aggregation in Agent Teams

There is a similar issue to do with aggregation of agents. In some circumstances, a fire truck containing fire fighters might be considered as one aggregated agent. In another situation it might be regarded as containing five separate agents depending on the context of whether the truck is mobile on the road or stationary near a fire front. RescueModel is a suitable framework for exploring these issues.

4.5 Agent-Friendly Environment Labelling

A goal of RescueModel is to use as much existing data as possible. This includes data in current file formats. For instance, MultiGen’s OpenFlight format has been developed for rendering three dimensional graphics in H-I-L simulation, and exploits satellite mapping and navigation databases for cultural feature representation. Presently, these databases are not labelled appropriately for agent simulation purposes. Unfortunately a design drawback of this format is that it has no raster terrain elevation concept like in Digital Terrain Elevation Data (DTED) [20] so the latter format must be integrated for the agents to do detailed terrain associated actions like contour navigation. RescueModel requires an agent-friendly combination of the two data sets (done via SEDRIS [21]) into an internal representation in memory which agents can reason about and also be accessible to physical models. A question that arises is whether a separate representation of the environment for agents and physical models is required.

5. Discussion

Possible application areas for RescueModel are shown in Figure 3. In simulation and computer science users might include researchers who need agent friendly environment representations, and who work in situated environment team coordination. Although a fire disaster has been chosen as a first scenario, the issues in human decision making that are addressed will be the same in many other fields. There is also the potential for use in human performance experiments if computer generated forces are required. Work has been done by Cottam and Shadbolt in search and rescue related to planning, scheduling and resource allocation in support of more efficient knowledge acquisition [22]. These issues could potentially be investigated using the framework. The RescueModel project is a follow up to [23].

6. Conclusions

RescueModel meets the need for a testbed vehicle for teamed agent studies. It has the potential to be a standard architecture. Although a fire scenario is being considered, any other time stepped model can be incorporated, for instance an earthquake disaster. It provides a high fidelity environment on which to explore and contrast agent team architectures and their interactions with the environment. The design has identified issues yet to be addressed and clarified in agent-enabled environment modelling. It integrates existing lines of work and opens the possibility of cross fertilisation of work in human decision making and agent architectures, areas which are presently unrelated.

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8. References


9. Author Biographies

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