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Agent teamwork and reorganization: exploring self-awareness in dynamic situations

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ABSTRACT

We propose attributes that are needed in sophisticated agent teams capable of working to manage an evolving disaster. Such agent teams need to be dynamically formed and capable of adaptive reorganization as the demands and complexity of the situation evolve. The agents need to have self-awareness of their own roles, responsibilities and capabilities and be aware of their relationships with others in the team. Each agent is not only empowered to act autonomously toward realizing their goals, agents are also able to negotiate to change roles as a situation changes, if reorganization is required or perceived to be in the team interest. The hierarchical 'position' of an agent and the 'relationships' between agents govern the authority and obligations that an agent adopts. Such sophisticated agents might work in a collaborative team with people to self-organize and manage a critical incident such as a bush-fire. We are planning to implement a team of agents to interface with a bush-fire simulation, working with people in real time, to test our architecture.

Keywords

Human performance modeling, reorganization, simulation, multi-agent systems

1. INTRODUCTION

Complex and dynamic decision making environments such as command and control and disaster management require expertise and coordination to improve chances for successful outcomes. Significant challenges include: high information load detracting from human performance [11, 18], coordination of information between parties involved needs to be well organized [22], sharing situation awareness amongst all relevant parties, and having an efficient adaptive organizational structure than can change to suit the needs presented by the dynamic situation [8, 11].

Using artificial agents as assistants to facilitate better coordination and information sharing has the potential to support studies of human decision makers and to improve disaster management training. Using disaster management domains as a 'playground' for virtual agent teams has the potential to provide insight on the design and structures of agent teams.

Exploiting a disaster simulation requires dynamic and complex team decision making task with an appropriate level of fidelity [28]. Our collaborators have developed a networked simulation program: Network Fire Chief (NFC) [19] that has been developed and used for training and research of the strategic management of a bush fire. NFC provides a realistic simulation of the fire disaster scenario. Using NFC also provides us with the opportunity to compare the behavior of our artificial agents with human agents engaged in the same simulation. We can draw on the data available describing how people react to a simulation to inform our design.

In this paper, we present preliminary analysis toward building adaptive BDI agent teams with self-awareness and team flexibility to enable dynamic reorganization. We will augment NFC with agents that have access to fire, landscape and resources information appropriate to the role they have adopted, and appropriate teamwork infrastructure. The agents will be able to work with humans to manage a simulated bush-fire. In the remainder of this paper, we outline the requirements of such agents and team infrastructure and our preliminary architecture for their implementation. We argue that self awareness in our artificial agents will empower them to 'thoughtfully' negotiate appropriate structural reorganization of the team. Disaster Management protocols demand that teams restructure when the complexity of a situation changes [2].

The remainder of this paper is structured as follows. In Section 2 we provide some background on the bush-fire incident control system and typical features of the teamwork required. In section 3 we provide some background on related work in multi-agent teams and we describe the requirements of our sophisticated virtual agents. In Section 4 we outline how we plan to integrate virtual assistant agents with humans to improve the communication, shared situation awareness and coordination between the parties involved.

2. DOMAIN BACKGROUND: BUSH FIRE MANAGEMENT

Typical characteristics of a domain that might benefit from sophisticated agent teamwork are: too large for any one individual to know everything, necessary for communication between agents (people or artificial agents) to update and share situation awareness. Each agent needs to be aware of their own responsibilities and work autonomously to perform tasks toward their goal. Agents need to work together in a coordinated and organized way. The nature of the dynamic and emerging situation requires that teams self organize and possibly re-organize during the life of the team.

The disaster management simulation is a well suited mini-world in which such sophisticated agents might be employed - responding as part of a team (of human and artificial agents) to an emerging disaster. In this disaster scenario, dynamic decision making and actions must be taken under extreme time pressure. Previously disaster simulation systems have been developed and used for studies of agent teamwork and adaptive agent behavior (e.g., [7, 21]).

A persistent problem in disaster management is the coordination of information between agencies and people involved [22]. An essential factor in coordination is to provide essential core information and appropriate sharing of this information [8]. It is not clear what exact level of shared mental model is required for effective teamwork. It may be that heuristics are used based on communication between team members rather than explicit shared models [15]. Using artificial agents to aid the flow of relevant information between humans involved in the disaster management has been implemented using R-CAST agents [13]. These artificial assistants were shown to help collect and share relevant information in a complex command and control environment and to alleviate human stress caused by the pressure of time [13]. These agents aided the coordination of information between people involved. Artificial agent teams themselves can have a team mental state and the behavior of a team is more than an aggregate of coordinated individual members' behavior [25].

Human performance modeling and behavioral studies have shown that information load can have a negative impact on performance (e.g. [11, 18]). The skills required to coordinate an expert team need to be developed in a realistic and suitably complex simulation environment [28]. Disaster management training involves following protocols and policies as well as flexible and responsive interpretations of these in practise [1]. Using synthetic agents in a realistic simulation to provide expert feedback and guided practise in training has been shown to be helpful [5, 28].

There are complex protocols available for incident control and coordination. These protocols define levels of command and responsibility for parties and agencies involved and the flow of communication. The organizational structure changes based on the size and complexity of the incident. Simulating and modeling complex command and control coordination has been useful as a tool for investigating possible structural changes that can help toward success. Entin and colleagues have investigated the effect of having an explicit command position: intelligence, surveillance, and reconnaissance (ISR) coordinator to help collaborative teams in command and control [1]. A collaborative team that is capable of reorganizing structurally as well as strategically during a problem scenario to adapt to a changing situation might perform better than a team with a fixed structure [9, 12]. Self-awareness and meta knowledge have been shown to be required in team simulation studies [27]. In diaster management, it has been suggested that one important mechanism needed for coordination is improvisation and anticipatory organization [22]. We speculate that agents that are capable of initiative and anticipation in terms of their coordination, need to be self-aware and aware of others in the team to enable anticipatory behavior. Anticipating configuration changes that might be required in the future, during team formation is critical toward reducing the time required to reform the team at that future time [17].

Protocols for fire management have been developed to define the actions and responsibilities of personnel at the scene. In Australia, the ICS Incident Control System [4] has been adopted (based on a similar system used in USA). During an incident, the ICS divides incident management into four main functions: Control, Planning, Operations and Logistics. At the outset of a fire disaster, the first person in charge at the scene takes responsibility for performing all four functions. As more personnel arrive, and if the situation grows in complexity, some of the functions are delegated with a team of people responsible for incident management. It may be that the initial incident controller is reallocated to a different role if a more experienced incident manager arrives.

In a large incident, separate individuals are responsible for operations, planning, logistics and control, and the fire area is divided into sectors each with a sector commander. In a smaller incident, the incident controller performs all functions, or may delegate operational functions to a operations officer.

In the period of a normal bush fire scenario, the management and control structure may be reorganized according to need as the size and complexity of the fire changes. In a recent study [18] investigating reasons for unsafe decisions in managing fires, two factors identified as impacting on decision-making are of interest to the current work. These were: 1. Shift handover briefings were not detailed enough and 2. lack of trust in information passed on regarding the fire if there was not a personal relationship between the officers concerned. We will revisit these factors in our plans for scenarios and trials in the current work. It might be possible to recreate such factors in artificial simulations and to support the handover of information at the end of a shift by having a detailed handover to a new virtual assistant agent potentially making extra information available to the new shift crew.

3. SOPHISTICATED SELF-AWARE AGENTS

The focus of the current work is to describe attributes needed in a sophisticated collaborative team of artificial agents capable of emergent team formation with flexibility in terms of the roles adopted and an ability to reorganize and change/handover roles during a scenario. We are interested to investigate if the BDI agent architecture can be successfully extended to create more sophisticated team agents for a particular domain. Unlike Teamcore agents [20] we are restricting our interest to a situation in which all the agents can be homogenous in design and can share access to a common workspace. We are interested to develop self-aware agents with a level of autonomy allowing them to reorganize during a simulated disaster scenario. Following from the work of Fan and colleagues [13], we are planning experiments to investigate whether sophisticated BDI team agents can be used as assistants to aid relevant information sharing between human operators in a complex and dynamic decision making context. Unlike Fan, we plan that our assistant agents can take on more than one role and may change roles during the scenario.

We have the added value that our agents will be interacting in a simulation system for which there is data available to describe realistic human behavior. We can be usefully informed by a comparative analysis of artificial agent behavior with human agent behavior responding to elements in the simulation [23].

3.1 Multi-agent Collaborative Teams

Multi-agent systems research has included work on teamwork and architectures for collaborative agent teams. Significant effort is being invested in building hybrid teams of agents working with people (e.g. [20, 26]) and fully autonomous agent teams (e.g., [7]). Heterogeneous agent teams have been created by using special TEAMCORE agent coordinators to act as mediators between team members [20].

Sharing situation awareness of a complex task is a difficult coordination problem for effective teamwork. Knowing what information to pass to whom and when this can be helpful is not a simple problem. Yen and colleagues have conducted research into the coupling of agent technologies to aid people in efficient decision making using distributed information in a dynamic situation [13]. They have successfully implemented agent assistants to aid humans share situation awareness in command and control situations.

The R-CAST architecture is based on recognition primed decision making RPD, making decisions based on similar past experiences. Each person involved in the command and control simulation is assisted by one or more RPD-enabled agent. The agents may collaborate together with other agents and with their human partner. The effectiveness (quality and timely decision making) of the team depend on effective collaboration - sharing of information proactively and in anticipation of the needs of others. The artificial agents help by: i.accepting delegation from the human decision maker to inform other agents and collaborate in making a decision; ii.the agent recognizing a situation and prompting their human partner, or iii.based on decision points explicitly provided in a (team) plan followed by an agent. Each artificial agent has access to a domain decision space based on cues (abstractions) of the information available. The agents perform similarity matching and refinement to choose the most relevant decision space. In the project described by Fan [13], the artificial agents monitor for critical situations and inform human operators when these occur. The agents also have access to a shared map of the situation and can update icons on individual workspace maps and on a shared general map if given approval. The R-CAST agents have been shown to help collect and share relevant information in a complex command and control environment and to alleviate human stress caused by the pressure of time [13]. The R-CAST agent team was fixed - each agent was assigned to a human counterpart for the duration of the scenario and each agent was limited to one type of decision. (If a person was performing more than one function, they were supported by more than one R-CAST agent, each operating separately.) One of our focuses is to explore the dynamic nature of the environment and to design agents that can change their role and adapt as the environment changes, as these are important features of our disaster management domain.

3.2 Team Reorganization and Autonomous dynamic role adoption

Research into organizational structures has involved agent teams in simulations to test how and when re-organization should occur (See for example: [9, 12]). There has been some agent research work in building adaptive agent teams that are capable of dynamic reorganization [16]. We are interested to progress this further by designing BDI agents that can negotiate their roles dynamically in an emerging team. Reorganization has been described as 2 distinct types: structural and state reorganisation [16]. Some progress has been made toward flexible strategic/state reorganization of teams. Matson and DeLoach have implemented algorithms for reallocation of new agents to roles to respond to situational changes (e.g. when agents are lost from a team) however they have not implemented structural reorganization in their agent team [16]. We are interested to provide our agents with some self-awareness and team awareness to enable the agents to decide upon structural reallocation of the roles required to fit the changing situation. It is hoped that our experimentation will clarify the level of knowledge and awareness needed to enable such reasoning.

The general Teamcore teamwork agent architecture is designed to rely upon team plans that are created at design time. These team plans define a hierarchy of dependencies between team and individual roles as well as a decomposition of team plans and sub-plans. There is no provision of opportunity for negotiation between agents to handover/swap roles as the agents themselves are not given a level of self awareness about the team structure nor team plan. Only the proxy agent is aware of current team plans, the actual domain agents are given instructions from the proxy agent In the current project, we are interested in homogenous agents who have a level of self awareness of their position and within the constraints of delegated authority rights, may be able to autonomously change roles or show initiative by performing an urgent task without 'permission' or delegation, or anticipate a future need. The ability for an agent to autonomously (within limits) take on initiative responsibilities or negotiate to handover to, or accept responsibilities currently adopted by another agent are desirable in the emergency management domain [2]. Tambe and colleagues have successfully implemented adjustable autonomy in agents to enable agents to transfer control to a human, however it is our interest to investigate agent properties that would enable artificial agents to negotiate with other artificial agents to handover roles. It is our goal to develop self-aware agents that can exhibit initiative and reason without the aid of a controlling or proxy agent manager, to self organize in response to the dynamic situation.

Collaborative agents require a meta level of additional self-knowledge in the agent to enable agents to negotiate. Agents need to know and possibly negotiate around their adopted roles and what actions they are capable of performing. An agent role can be defined statically at design time - in terms of goals to be performed or the role might be more flexible and negotiated dynamically - to enable more flexible and adaptive team reorganization at run time. Providing the infrastructure to enable an agent to be more flexible and to enable the reorganization of teams requires a more sophisticated agent design than the BDI approach of itself provides and more resources. According to the domain and level of sophistication and reorganization needed, the decision to 'keep it simple' or to include more complicated structures is a trade off between flexibility and extra resources and structure required. Agent roles can be defined to scope the sphere of influence an agent might have and to enable agents to balance competing obligations [24].

3.3 Relationship awareness

Organizations have been described as complex, computational and adaptive systems [6]. Based on a view of organizational structure and emerging change in organizations with time, Carley and Hill have suggested that relationships and connections between agents in a network impact on the behavior in organizations. Relationships and interactions are claimed to be important to facilitate access to knowledge. "Whom individuals interact with defines and is defined by their position in the social network. Therefore, in order to understand structural learning, it is particularly important to incorporate a knowledge level approach into our conceptions of networks within organizations." P.66 [6] This work may suggest that for teams involving artificial agents involved in a dynamic and emerging organizational structure, it might well be worth investigating the significance of relationship awareness to enable appropriate interactions between agents. In the disaster management domain, there is evidence that suggests that relationships between people have an impact on their level of trust in communication (apart from the roles being performed) [18]. It is not in the scope of our research to investigate trust between agents, however it may be interesting to be able to create 'personal' relationship links between agents in addition to positional links due to role hierarchies and show the impact of these in a simulation.

3.4 Toward defining the sophisticated agent team

Bigley and Roberts [2] conducted a study of the Incident Control System as employed by a fire agency in USA. They identified four basic processes for improving reliability and flexibility in organizational change: Structure Elaborating, Role Switching, Authority Migrating, and System Resetting. Structure elaborating refers to structuring the organization to suit the situation demands, role switching refers to reallocated roles and role relationships, authority migrating refers to a semi-autonomous adoption of roles according to the expertise and capabilities of the individuals available,

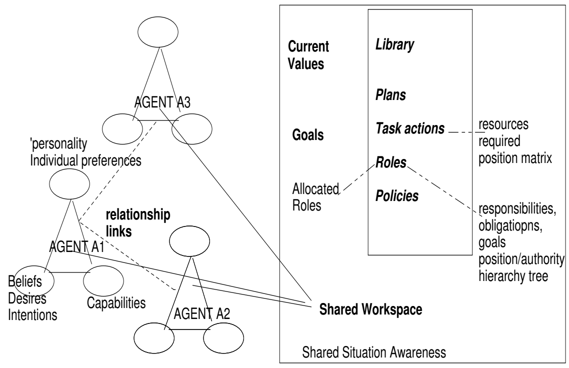

Figure 1: The proposed BDI agent team architecture

system resetting refers to the situation when a solution does not seem to be working and a decision is made to start with a new organizational structure. These four processes can inform the agent team architecture. The agent teams structure will be established so that common team knowledge is available and where appropriate, sub-teams are formed [24].

A proposed agent team architecture (based on BDI architecture) is as follows: Dynamically allocate tasks (responsibilities (obligations), actions, goals) to a particular 'role'. Allow agents dynamically adopt, refuse, give up, change and swap roles. Maintain a central dynamic *role library*, accessible to all agents in which roles are defined. Figure 1 shows this architecture.

Agents require a level of self awareness: know their own capabilities, know their current 'position' in the team (based on current role), know the responsibilities associated with the role currently adopted (if any), know relationship linkages existing between roles and (if any) 'personal' relations between agents, know their obligations, know their responsibilities for any given time period, know their level of delegated authority and what tasks can be done autonomously, without requesting permission or waiting for a task to be delegated. Agents must adhere to published policies governing behavior. All agents have access to a shared workspace representing a shared mental model of the situation. In addition, agents have their own internal beliefs, desires and intentions. Agents potentially could also have individual preferences governing features such as willingness to swap roles, likelihood of delegating or asking for help etc.

This architecture allows for some domain knowledge to be encoded in plan libraries, role libraries and task descriptions at design time. However, it allows for agents to update role allocations and current shared mental models dynamically. There is no attention management module made explicit, but this and decision management processes (c.f. R-CAST architecture, [13] are important and will be provided by the underlying BDI architecture.

Agents might be required to show initiative - by volunteering to take on roles they are capable of performing or have particular expertise with, if they have the time and resources to devote to such roles; by taking action in an urgent situation when there is no time to negotiate or delegate.

3.4.1 Managing reorganization in the team

3.4.1.1 Time periods

Work in time periods, such that for any time period, t, the team structure is static, but then at a new time period t +k, the environment has changed, significantly enough to warrant reorganization of the team. (k is a variable amount of time, not a constant.) The leader controlling agent would decide that reorganization was required or could be prompted to reorganize by a human team member.

At the start of a new time period t', the team leader could call a meeting and open the floor for renegotiation or roles, alternatively, two agents can at any time agree to handover or swap roles and then note their changed roles in the current role allocation in shared workspace. A mechanism for agents being able to define/describe/be self aware of their obligations and relationships is needed so that the agents can (re)negotiate their roles and responsibilities allowing a team structure to emerge in a dynamic way.

3.4.1.2 Coordination and Control

This is a situation of centralized decision making, where there is an ultimate leader who has authority and a chain of command hierarchy, c.f., [23]. The team members are locally autonomous and responsible to make local decisions without need of permission, using the local autonomous/Master style of decision making (Barber and Martin, 2001, cited in [10])

One approach for the support and control of an agent team is to use policy management to govern agent behavior. This enforces a set of external constraints on behavior - external to each agent. This enables simpler agents to be used. Policies define the 'rules' that must be adhered to in terms of obligations and authorizations granting permissions to perform actions [3]. It is planned to have a set of governing policy rules defined in the central library.

To achieve coordination between agents, one approach is to also control interactions via external artifacts - similar to a shared data space between agents, but with an added dimension of social structure included [14]. This will hopefully be achieved in our system with the shared workspace and providing agents access to current role allocations including relational links.

When agents join the team they agree to accept a contract of generic obligations and some general team policies [3] as well as some more specific obligations that are associated with specific roles. In addition to obligations (responsibilities accepted that must be adhered to), an agent may have authority to ask another agent to perform a particular task or adopt a role, or authority to perform particular actions. These actions could be (for example) to drive a truck to a location and turn on the fire hose to fight a fire at that location, or to order another agent (with appropriate authority and access) to drive a truck to a location and fight a fire, or to accept a new role as a sector commander in a newly formed sector.

Obligations are based on position in the hierarchy. E.g. if a leader (or agent in higher ranked position than you) asks you to take on a role, you are obliged to agree, but if a 'peer' asks you to swap or handover a role, you may reject, or open negotiations on this.

Table 1: Example Position-Delegation-Action Matrix

Action	Agent Position		
	P1	P2	P3
Act1	0	0.5	0.5
Act2	1	1	1
Act3	-1(3M,4I)	-0.5	0.5

3.4.1.3 Delegation and Authority to act autonomously

The imagined organizational structure is such that there is controlled autonomy enabling automatic decision-making by agents on some tasks and requiring that other tasks be delegated, coordinated and controlled by a 'leader' agent. Examples of automatic decisions that might be authorized as possible without involving permission from a more senior agent are: two peer agents agree to swap roles; or two agents might agree to work together to work more efficiently toward realization of a particular task.

An agent's position in the team hierarchy defines the level of autonomy allowed to that agent to perform actions. Actions are defined in terms of required agents and position levels needed to perform this action.

A *Position-Delegation-Action Matrix* could be defined as shown in table 1.

Each empty cell may contain a code to indicate the level of autonomy afforded to perform an Action (Act n) for an agent with the corresponding position Pm. Possible codes include : 0 - Never permitted, 1 - Always permitted, 0.5 - may request permission and act alone on Act n with permission, -0.5 - may engage in teamwork to help others to perform this Act n, -1 - must engage in teamwork to perform this Act n, cannot be done alone. In the latter two cases, where agents might work as part of a team on an Action, then there needs a representation of the required minimum, M number of agents and the 'ideal' number of agents needed to successfully perform this task. This could be represented in parentheses (Act3 with agent in position P1 requires at least 3 agents to perform, and ideally is performed by 4 agents).

3.4.2 Roles and Responsibilities

Below we describe some responsibilities that could be associated with generic roles. These roles will be elaborated in future to include more specific responsibilities based on the protocols defined in the Australian incident control system (discussed in the next section).

3.4.2.1 Example responsibilities associated with generic Leader role defined at design time

- Forward planning, anticipate resource needs for near future (time t+k)

- Broadcast/request resource needs and invite other agents to adopt the responsibility to fulfill these resource needs
- Accept an agent (A) 's proposal to adopt a role (R) for time period (P: between time:ttn)
- Agree/negotiate with an agent on the list of responsibilities (RS) allocated to a role (R)
- Set a time for a (virtual) team meeting and set invitations/broadcast messages to some/all agents to participate
- Keep a mental picture of the current team structure: resources available, the 'position' of these resources in the team hierarchy

3.4.2.2 Example responsibilities associated with generic Team Member role defined at design time

- Be aware of own capabilities (C) and access to resources
- Only volunteer/accept responsibilities set RS that are in agent's current capabilities set (RS = C)
- Act reliably, i.e., don't lie and always act within assigned responsibilities and policies
- Have self-knowledge of own position in the team hierarchy, and know what delegated rights and authority to act are available
- Be flexible : prepared to abandon an existing role in favor of a new role that has a higher priority
- Be prepared to handover/swap a role if asked by a leader or an agent with position of authority higher than self
- Be prepared to negotiate with peers to swap/handover roles if of team benefit
- Volunteer to take on a new role if you are capable and have access to all needed resources
- When agent can not predict success, or experiences failure in attempting current responsibility, relinquish that responsibility according to agreed policy

4. TEST SCENARIO

4.1 Experimental design

The scenario planned for our experiment involves a team of human sector commanders each managing a separate sector of land under threat by a spreading bushfire. There is one overall fire controller. Each sector commander can communicate with other commanders, but has access to information updates regarding the spread of fire their own sector only. The sector commanders choose when and how much information is passed on to the incident controller. Following from the work of Yen [13], we plan to have a virtual assistant agent assigned to each human agent involved in the management of the scenario. These virtual assistants will have read and write access to a shared workspace regarding the current state of the fire and awareness of their own network of relationships to other agents in the team. The R-CAST agents were shown to help collect and share relevant information in a complex command and control environment and to alleviate human stress caused by the pressure of time [13].

Each assistant will adopt one or more roles from the role library according to the role allocated to their human counterpart. If their human counterpart changes or delegates some of their roles, it will then be necessary that the agents negotiate to update their roles so that they are still helpful to the person they are paired with. Agent assistant roles will include: Incident Controller, Sector Commander, Operations officer, planning officer, logistics officer. Initially, when the fire size is small, the incident controller will also be performing the role of operations officer, planning officer and logistics officer. As the fire grows and spot fires appear, some of these roles will be delegated to new personnel. At this stage, the agents will be asked to reorganize themselves and dynamically update their roles accordingly.

In addition to the assistant agents, there will be additional agents in monitoring roles. These agents will update the shared mental workspace with updates on situation awareness. The monitoring agents have limited information access, so there is distributed awareness across multiple agents of the overall situation. These monitoring agents will monitor changes to the fire disaster in one sector. We might also engage specialized monitoring agents with specific roles to protect particular resources in the landscape e.g. a house.

4.2 An example

A fire is spreading across the landscape, each agent role is either responsible for an appliance such as Fire Truck, Bulldozer or Helicopter, or is responsible for monitoring the landscape in a particular area, or is acting as a dedicated assistant to a human agent. Agents adopting the monitoring agent roles have limited information, so that there is distributed awareness across multiple agents of the overall situation. These monitoring agents are responsible for initiating information flow to other monitoring agents and people - or perhaps for updating a central 'map' or shared awareness space with abstractions summarizing significant data. Each monitoring agent role has visibility of one sector only.

Landscape is broken into 3 sectors; each sector has a human sector commander. Each human sector commander is helped by a monitoring agent that has visibility and awareness regarding that sector of landscape. In one sector, there is a house on top of a hill. A fire is spreading toward this sector from an adjoining sector. Wind direction is encouraging the spread of the fire and if it keeps traveling in this direction, it will take off up the hill and endanger the house.

There are a limited number of fire-fighting appliances: 2 fire trucks, 1 bulldozer, 1 helicopter. The incident controller is aware of all appliances and the sector they are located. Sector commanders are only aware of resources in their own sector. Assistant agents are allocated to assist each sector commander, and in the roles corresponding to the four main functions in the ICS. Special protective monitoring agents are responsible for monitoring threat to a particular resource - e.g. house, tree plantation, etc. The fire begins in sector 1, spreads toward sector 2. The house is in sector 2. The helicopter is at home base in sector 3. The house needs protection. The agents and sector commanders will need to mobilize resources to stop the fire spreading and save the house.

5. DISCUSSION

This design is yet to be implemented, although preliminary feasibility study has been conducted to test if agents would be able to satisfactorily access the landscape and simulation information within NFC. This would enable our synthetic agents to automatically access the simulation environment in a similar way to human agents would. It is planned that development on our BDI agents will begin in 2006. It is not in the scope of this project to investigate agent coordination and communication protocols, nor agent negotiation protocols. These aspects will be informed by existing research in these areas.

It is not an aim of this project to replace human fire controllers with artificial agents, rather to use the fire fighting domain as a good case study to implement and test our team structure in a controlled, but realistically complex, dynamic virtual world. It is hoped that our agents will be sophisticated enough to be able to (at least partially) replace human agents in the simulation training exercise and that we can compare human behavior with artificial agent behavior to inform our design. It may be that our work provides agents that could assist humans in the real-time management of dynamic disasters, however we make no claims that this will be so.

It is our intention to implement agents to meet our proposed requirements and interface these agents in the virtual simulation world of NFC and observe their collaborative behavior. Our particular interest initially is to see if the agents can communicate with each other in a way to provide assistance to the humans involved in improving shared situation awareness. Also, we are interested to see how the agents perform in team reorganization. In the initial stages, it is our intention to create a simulation involving agents as assistants to the key human personnel involved in the fire management.

In later simulations, we hope to be able to substitute virtual (expert) agents for human agents in the management scenario and perhaps use such agents to aid with training exercises. It has been found that providing expert examples of dynamic decision making in repeated simulations can help improve human performance [5, 28], there might be potential for our agents being used in training of incident management teams with virtual disasters in NFC. There also possibilities to use the NFC as a playground for an entirely virtual team and investigate the reorganizational and collaborative capabilities of our team agents within this mini-world.

This is work in progress. This paper describes our position in terms of how sophisticated agents might be structured in a team. We are planning to create specialized agents who share access to a role library and share team goals. We propose that the agents require awareness of their own position and relationship to others in the team, be committed to team goals, accept leadership and authority and be prepared to be flexible and adaptable - to handover responsibilities or swap roles if necessary. We are designing agents with an team infrastructure to support dynamic reorganization.

6. ACKNOWLEDGEMENTS

The authors thank Dr. Mary Omodei and her team at La-Trobe University for their support with Network Fire Chief software and disaster management issues in the firefighting domain.

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