The Human Agent Virtual Environment

Michael Papasimeon
Defence Science and Technology Organisation
506 Lorimer Street,
Fishermans Bend, VIC. 3207
Australia

Adrian R. Pearce
NICTA Victoria Laboratory
Department of Computer Science and Software Engineering
The University of Melbourne
Victoria, 3010, Australia

Simon Goss
Defence Science and Technology Organisation
506 Lorimer Street,
Fishermans Bend, VIC. 3207
Australia

ABSTRACT
In this paper we describe a multi-agent simulation called the Human Agent Virtual Environment (or HAVE). HAVE is a test bed to explore agent-environment interaction in multi-agent simulation for defence applications. The primary research driver in the development of HAVE is to explore representations of virtual environments in which both humans and agents are situated, perceive these environments and undertake meaningful and appropriate actions. HAVE models a joint simulation of a Close Air Support (CAS) mission which involves fighter or strike aircraft providing support to ground troops through the use of air-to-ground weapons. This provides a realistic and currently extremely relevant domain in which to explore agent-environment interactions. Three important research challenges have been addressed by the work. The first is the implementation of a multi-modal representation of the virtual environment, having multiple, parallel yet consistent representations of the virtual world that were accessible to, and tailored for the different simulation components. The second is the use of labeled annotations in the virtual world which the agents could easily access and interpret. The third, the use of an appropriate architecture for capturing and representing interaction between agents and the environment they are situated in.

Categories and Subject Descriptors
I.2.11 [Distributed Artificial Intelligence]: Intelligent Agents; D.2.11 [Software Architectures]: Domain-specific architectures

General Terms
Algorithms, Design

Keywords
Multi-Agent Simulation and Modeling, Agents and Cognitive Models, Defence

1. INTRODUCTION
The Human Agent Virtual Environment or HAVE is a military simulation concept demonstrator developed to conduct research into agent and human interactions in virtual environments. It is a part of larger research and development program into using multi-agent systems for military simulation of air operations, spanning a period of over fifteen years. What started out as research into modeling situational awareness for fighter pilots has seen the deployment of multi-agent simulations for providing advice into multi-billion dollar military acquisition decisions [8]. Key to the approach has been the focus on interaction, from both the agent-environment, human-environment and agent-agent perspectives (see [9] for further details).

Research and application challenges shifted the focus to the interaction between agents and their environment: the need for closer interactions between air, ground and naval forces; increasing sophistication in command and control networks; and the rise of military experimentation as an important tool in many types of analysis. There has been additional demand for intelligent agents as adversaries or team mates in simulators used for training and concept of operations development. Motivating the development of HAVE was the successful deployment of an AP-3C maritime patrol aircraft simulator, in which agents and humans were successfully interchanged in a simulator used for both operations research and tactical development [9]. The agent-oriented design of the simulation architecture allowed a team of agents representing the crew of the maritime patrol aircraft to be replaced by a real crew, thus turning a constructive wargame into a human-in-the-loop simulation. A research challenge arising from this deployment, was to investigate hybrid human-agent teams, containing both human and agent crew members. Another related research challenge was the investigation of ways placing agents in virtual environments (as either virtual adversaries or team mates) that were originally designed for humans. This includes the use of agents in flight simulators which have high fidelity graphical displays with all their interfaces designed for human rather than agent interaction.

HAVE was developed to facilitate a more realistic, complex and dynamic simulation domain that was relevant to the types of air operations being studied. The research challenges were quite large in scope and therefore three main ideas were explored in HAVE as starting point. The first idea was to implement a multi-modal representation of the virtual environment. This meant having multiple, parallel yet consistent representations of the virtual world that were
suitable and accessible to the different simulation components. The second idea was to investigate the use of labeled annotations in the virtual world which the agents could easily access and interpret. Finally, the third idea was to investigate the use of alternative architectures for agent reasoning that better captured the interaction between agents and the environment they are situated in.

Ideas and concepts were adopted from the theory of affordances. Affordances are a theory from ecological psychology that describes how humans and animals can perceive the possible actions that the environment affords them. See Section 4 for further details.

Understanding the agent-environment interaction is becoming increasingly important in many different types of defence simulations, and lessons learnt from HAVE will be applied to the development of larger scale multi-agent simulations for operations research, training, war-gaming and military experimentation.

In Section 2 different applications of military simulation which make use of agents are described and the reason for the development of HAVE is placed into context. This is followed in Section 3 by a description of the domain of Close Air Support which is simulated. This includes an overview of why this domain was suitable for the work presented here. This is followed by a detailed discussion of the research challenges which motivated the development of HAVE in Section 4. In Section 5 more details about the software architecture used in HAVE are provided. This involves a high level description of the major components of the architecture, followed by descriptions of the representation of the virtual environment and the way in which the agents in HAVE were designed. The paper concludes in Section 6 by outlining some of the lessons learnt for multi-agent military simulation as well as briefly describing some of the possible future work which may be undertaken with HAVE.

2. AGENTS IN MILITARY SIMULATION: RELATED WORK

The applications of military simulation have been many and varied. Perhaps best known is the use of computer simulation for the purposes of training military operators. Flight simulators with high fidelity image generators are a well known example of training based application of simulation.

There has also been a large amount of work in the area of simulating military air operations in operations research and war-gaming for the purposes of providing advice for acquisitions, or for developing military tactics and concepts of operations [17].

Intelligent agents have been used in these types of military simulations for a number of years to act as human surrogates of military operators. The use of agent technology in simulation has been more prevalent in the operations research field where there has been a demand for sophisticated and explainable representations of tactical decision making [10]. Although agent technology has at times been used in military flight simulators for training purposes (which are typically known as Computer Generated Forces or CGFs), they have not always matched the complex tactical behaviors implemented in operations research based multi-agent simulations [12].

Related work in the use of intelligent agents for military simulation has focused more on developing the agent reasoning processes themselves [11], agent collaboration and teamwork models [18] or on the development of simulation models utilized [16], rather than exploring and understanding the agent-environment interaction.

The recent push towards military experimentation by a number of militaries around the world [19], has placed additional demands and constraints on how military simulators are constructed. This has meant that there is a greater emphasis on how humans and virtual forces (namely intelligent agent based technologies) interact not only with the virtual environment represented in the simulation but also with each other.

This requirement to experiment with novel tactics and concepts of operations has also meant that simulation systems that were previously only used for either training or for operations research purposes are now required to interoperate. There are a two important consequences for intelligent agents in these military experiments. First, in the case of training simulators, agents are being asked to perceive and act in virtual environments that were never designed to operate in, primarily because these environments were designed for humans. Second, there is a greater demand for human-agent interaction and particularly for hybrid human-agent teams. The Human Agent Virtual Environment (HAVE) was developed to explore these two issues, which are described further in Section 4.

3. CLOSE AIR SUPPORT

HAVE implements a simulation of a Close Air Support or CAS mission. Close Air Support is a type of air operation in which fighter or strike aircraft provide support to ground troops through the employment of airborne weapons. Typically a specially trained military operator on the ground known as a Forward Air Controller (FAC) or as a Joint Terminal Attack Controller (JTAC) will call in an air strike over radio and guide or talk-on a pilot onto a target that is posing a threat to ground troops. The target may be anything from enemy troops and vehicles such as tanks as well as other infrastructure. The talk-on the FAC/JTAC provides to the pilot must be accurate to avoid unnecessary collateral damage, civilian casualties and the risk of fratricide. This usually involves either a verbal descriptive location, a set of GPS coordinates and at times an identification of the target using a ground based laser. It is then the pilot’s responsibility to positively identify the target, ensuring the rules of engagement are satisfied and launch the required number of weapons. In modern CAS operations, this is typically a laser or GPS guided munition. CAS operations by strike fighter aircraft are usually conducted in pairs, with the lead aircraft dropping munitions while the wingman looks out for ground and air threats. Such threats, flying low to the ground, strict rules of engagement, the need to avoid fratricide and civilian casualties as well as time sensitivities all make the CAS mission one of the most challenging a military aviator has to face, especially in the case of urban warfare.

The CAS mission was the domain selected for HAVE for a number of reasons. First, it provides interesting and differing interactions with the environment both from the ground perspective (friendly and enemy ground troops, FAC/JTAC) as well as from the air. Second, it provided the opportunity for agents and humans to interact in the one virtual environment. A FAC or JTAC coordinating a strike on an enemy
4. RESEARCH CHALLENGES

4.1 Agent-Environment Interaction

A number of research challenges motivated the development of HAVE. The first was the need to integrate agents into simulation systems that were designed primarily for human interaction. This is the case for many flight simulators (civilian and military) that are used for training purposes. The training requirements in these types of simulators means that visual realism in the computer generated graphics is a primary driver. The underlying representation of the environment is typically a scene graph (or similar graphical database) which has been designed and optimized for the purposes of efficient graphical rendering. While integration of agents into these types of virtual environments is certainly possible, it is not necessarily easy, as the underlying data structures were not designed to be easily amenable and accessible to agent systems.

4.2 Agent-Human Interaction

The second research issue was related to the requirement for agents and humans to interact in the same virtual environment. In military simulations two types of human-agent interaction are usually considered. The first (and more common) interaction is that between a human operator and a virtual adversary. The second and perhaps more challenging interaction is the case where agents act as virtual teammates in hybrid human-agent teams. Both cases present unique and challenging problems.

4.3 Possible Approaches

These issues can be addressed in a number of ways. For example, it is possible to annotate a virtual environment such as a graphical scene graph in a way in which the annotations are easily accessible and provide utility to the agents situated in the world. The annotation of virtual environments for intelligent agents has been looked at in related work by Doyle [5, 4] and others. Another approach considered was to design the simulation architecture in a manner which transformed the scene graph into a form suitable for the agents in the simulation. As a first step in exploring these research issues a number of alternative approaches were tried in HAVE. This included the use of multi-modal environments and the perception of affordances or action possibilities by the agents.

A multi-modal environment means having multiple, parallel yet consistent representations of the environment. Initially this meant having two synchronized, independent and parallel representations of the virtual environment, one for the agents and one for humans, hence the name Human Agent Virtual Environment. This meant that a scene graph (or other graphical database) could be used to represent entities to be rendered so that the human operator could perceive the virtual environment. At the same time an alternative representation of the environment could be maintained that was in a form that was amenable and accessible to the agents. These were considered as two different modalities (or representations) of the same virtual environment with the constraint that they needed to be kept synchronized. For example, if an entity was destroyed it needed to be removed from both modalities.

The idea of having multiple modalities of the virtual environment seemed to be particularly useful especially in the context of a military simulation. Although initially the agent and the human were two primary modalities considered in HAVE, the number of modalities were extended to represent many different aspects of the virtual environment both traditional and abstract. This was important in a military simulation because the idea of an environment is extended beyond what is physically present and what agents can visibly see with their eyes to more abstract notions of environment. The abstract modalities include the social environment where teams of agents and the command and control relationships between them become important [18]. Each modality of the virtual environment not only represents what exists (and associated properties and attributes) in that modality but also captures the relational attributes between entities, where an entity maybe a simple object, an agent or a complex team of agents. The specific modalities of the virtual environment used in HAVE are described further in Section 5.4.

The second approach to exploring the agent-environment interaction in HAVE was to develop an affordance based agent reasoning model. Affordances are action possibilities that an agent perceives in the environment it is situated in. The theory of affordances was developed by Gibson [6] and is one of the important concepts in the field of ecological psychology; the study of how humans and animals interact with their environments. Gibson proposed the idea that humans and animals can not only perceive the properties and attributes of entities in the environment, but they can also perceive relational properties. More specifically humans and animals can perceive action possibilities with respect to particular entities in the world that afford them some behavior, hence the name affordances. The perceived affordances are
constructed using Open Scene Graph (OSG) [2] which is built on top of OpenGL. Parts of the DirectX library are used for human input devices such as a throttle and stick to fly the strike fighter aircraft and a steering wheel used to drive and control the tanks in the simulation. Three dimensional audio effects are implemented using the FMOD sound library. The aircraft platform is based on the well known and high fidelity JSBSim flight dynamics model [1]. This has been augmented with a custom built flight control system which has an autopilot capability which can be easily toggled from the HAVE user interface. The combination of realistic graphical rendering, three dimensional audio, human input devices and high fidelity vehicle models allows HAVE to provide a realistic and immersive experience for the human pilot.

A block diagram of the HAVE architecture is shown in Figure 2. The Visualization and Simulation Engine subsystems are two of the most important components of the architecture. The Simulation Engine not only consists of the simulation execution modules but also includes all modalities of the environment (including those suitable for intelligent agents). The scene graph representation of the virtual environment is kept separate and the VizSimBridge subsystem acts as a bridge between these different environmental representations and ensures that they remain synchronized.

Every entity in HAVE which is executed during the simulation is derived from the SimObject class as shown in Figure 3. This includes entities such as tanks and aircraft which are derived from SimEntity, sub-components (such as sensors and weapons) which are derived from SimComponent as well as the various environmental modalities which are derived from SimEnvironment.

5.2 Tank Model

The tanks can represent enemy targets, or friendly tanks carrying FACs or JTACs which guide the incoming CAS aircraft. The tank model consists of a vehicle dynamics models (controllable by an agent or by a human using a steering wheel), as well as visual sensor model, a radio model and a simple tank driver agent implemented using a finite state machine approach.

1A FAC (Forward Air Controller) or JTAC (Joint Terminal Attack Controller) is a ground based military operator who directs pilots onto specific targets.
5.3 Strike Fighter Model

The strike fighter model in HAVE represented an Australian F/A-18 Hornet with a weapons and sensor load-out configured for a Close Air Support (CAS) mission. Figure 4 is a UML class diagram indicating the various components which represented this aircraft. Each component had a unique role to play in successful undertaking of a CAS mission.

Platform The aircraft platform model was composed of the flight dynamics model and flight control system. The JSBSim based flight dynamics model allows for the representation of the flight characteristics of any aircraft using an XML based configuration file. The flight control system model was custom developed for HAVE and included an auto-pilot mode and an interface that let it be controlled by a human (using a throttle and stick) or via high level commands sent to it by a pilot agent.

Radar The radar model represents the typical capabilities of a radar found on a fighter aircraft. This included the capability to scan and track targets using multiple air-to-air and air-to-ground modes. For the Close Air Support mission, the radar is used in one of the air-to-ground modes to find ground targets such as tanks.

RWR The Radar Warning Receiver (RWR) is a sensor that detects air and ground based radar signals to determine if an enemy aircraft or enemy ground based air defence system obtained a lock on the strike fighter. The tracks from this sensor allow either the human or agent pilot to detect the direction of an enemy threat and undertake the required evasive action.

Visual The visual model represents the pilot’s eyesight. It is used to identify air and ground targets.

FLIR The FLIR (Forward Looking Infra Red) sensor is similar to the visual sensor except that it provides an infra-red image of the target to the pilot. It also has a longer range than the visual model and the ability to change the field of view to one of narrow, medium or wide. The FLIR is the primary means of identifying and designating ground targets for the pilot on a CAS mission.

Laser Designator Once the pilot has identified a target with the FLIR, he uses the laser designator to illuminate the target with a bright laser beam. The reflected laser beam can be detected by a laser guided bomb launched either by the pilot from the designating aircraft or from another aircraft such as the wingman.

LGB The laser guided bomb (LGB) model represents a free fall bomb which has a laser guidance kit added. The guidance kit can detect reflected laser radiation either from an airborne or ground based laser designator. In HAVE the only munition modeled was the GBU-12, a 500 lb laser guided bomb typically used on Close Air Support mission for destroying targets such as enemy tanks.

Pilot The pilot model could either be a human or an agent. The interface to the rest of the strike fighter allowed the pilot model to receive all the necessary information from the various aircraft systems (such as platform state, sensor state and tracks) as well as having the ability to send commands to each of these systems. For the human pilot the interface into the virtual environment consisted a graphical rendering of a cockpit view with a Heads Up Display (HUD), sensor views such as a radar scope and FLIR display as well as the ability to control all the systems using a throttle and stick. The pilot agent had the same capabilities as the human agent, except that there was a purely software interface into the virtual environment. More details about the internal design of the pilot agent model can be found in Section 5.5.

5.4 Multi-Modal Virtual Environment

In Section 4 the idea of a multi-modal representation of the virtual environment was presented. This approach allowed for multiple representations of the virtual environment that were suitable for different types of models. Originally it was intended that this would apply to two representations of the world; one for the human operator taking in the simulation and one for the agents. The concept however was extended to include other environmental modalities allowing custom representations of the environment for components such as sensors. The various environmental modalities not only represented individual simulation entities but also explicitly modeled and represented the relations between these entities. In this section, we briefly describe the different modalities represented in the HAVE simulation.

All simulation entities that had a physical presence in HAVE manifested themselves in the physical modality, which also included a collision detection and response capability. Not all simulation entities had a physical manifestation. Teams of agents such as sides, forces and squadrons were explicitly represented in HAVE. The concept of a team of
agents is an abstract social concept which doesn’t necessarily have a physical locality. Furthermore in a military context, the relationships between teams of agents in terms of command and control (C^3) concepts need to be explicitly represented. Therefore a team modality that incorporated concepts of teamed agents, social structure and command and control concepts was explicitly represented in HAVE.

The electromagnetic environment was also represented in HAVE using a number of modalities. Entities capable of emitting radar signals (such as fighter aircraft with a radar) as well as entities which had a radar signature (capable of reflecting radar energy) were represented in the radar modality. Components such as radars, radar warning receivers and radar jammers all interacted via the radar modality. Similar modalities were also available for other parts of the electromagnetic spectrum. These included visual, infra-red, laser and radio communication modalities of the virtual environment.

The graphical modality is a lighted, visual representation of the world using a scene graph implemented using the OpenSceneGraph rendering engine. This was the view presented to the human operator. It also included a set of graphical effects (such as the addition of ground and cloud textures) which provided additional visual realism for the human, but had no explicit representation in any of the other environmental modalities.

The agent environmental modality was the most important modality with respect to the research issues described in Section 4. This modality was a representation of the virtual environment that was suitable and accessible for agents. This meant that the information was presented in a way consisting of basic labels and annotations that the agent could perceive through its sensors. This removed the complication of having to access and transform information from a more complex representation designed for another purpose such as a scene database designed for graphical rendering.

Various types of information were represented in the agent environmental modality. The information included simple labels and annotations on the entities the agent could perceive with the various sensors. Traditionally tracks from a sensor provide information such as the range and relative orientation. The fighter pilot agent in HAVE could designate a track of interest using the FLIR and laser designator, which resulted in a set of additional entity annotations available to the pilot from the virtual environment which the pilot could access without having to model a detailed perception process. The complete set of labels is listed in Table 1.

<table>
<thead>
<tr>
<th>Annotation Type</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Aircraft</td>
</tr>
<tr>
<td>Role</td>
<td>Fighter</td>
</tr>
<tr>
<td>Status</td>
<td>Damaged</td>
</tr>
<tr>
<td>Object Type</td>
<td>F/A-18</td>
</tr>
<tr>
<td>Side</td>
<td>Blue</td>
</tr>
</tbody>
</table>

Table 1: The primary types of annotations provided on sensor tracks in HAVE. These annotations are used by the pilot agent to reason about the entities it can perceive in the world.

Table 2: As the pilot gets closer to a potential ground target, more information (or levels of detail) becomes available. The table indicates the types of labels/annotations that become available to the pilot as he/she goes through four stages of perception (Detection, Classification, Recognition and Identification).

<table>
<thead>
<tr>
<th>Class</th>
<th>Role</th>
<th>Status</th>
<th>Object Type</th>
<th>Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detected</td>
<td>●</td>
<td>● ●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Classified</td>
<td>● ● ●</td>
<td>● ● ●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Recognized</td>
<td>● ● ●</td>
<td>● ● ●</td>
<td>● ●</td>
<td></td>
</tr>
<tr>
<td>Identified</td>
<td>● ● ●</td>
<td>● ● ●</td>
<td>● ● ●</td>
<td></td>
</tr>
</tbody>
</table>

 possessed a number of interesting characteristics. The agent architecture was goal based, made use of ideas from Gibson’s theory of affordances and involved a four step process of agent reasoning based on John Boyd’s Observe-Orient- Decide-Act (OODA) model of fighter pilot decision making. Agent architectures based on the OODA model in conjunction with the BDI model [14] have been successfully integrated and deployed in some very large agent based simulations used in air operations research studies.

As briefly described in Section 4 affordances are action possibilities that a human or animal can undertake in the world. In HAVE, the concept of affordances was adapted and applied to agent reasoning in the virtual world. Specifically the concept of an affordance with respect to a particular entity in the world was used. The idea of a simple action possibility was extended from a simple atomic action to a more complex sequence of actions resulting in a goal possibility. This meant that as the fighter pilot agent made its way through the virtual world it reasoned about what affordances (action and goal possibilities) were available with respect to the different entities it could perceive using its various sensors. This list of affordances were then presented to the agent which could decide if it should continue to execute its current goal or to adopt a new one. These process were conducted in the context of a simplified OODA decision making loop as follows.

**Observe:** The agent observes and perceives the world by processing the information obtained from the various sensors available. This includes radar, FLIR, visual, radio and RWR.

**Orient:** Using the observations about the various entities in the world, the agent reasons about what affordances are available to it with respect to these entities.

### 5.5 Pilot Agent Architecture

The agent architecture for the fighter pilot agent in HAVE is a four stage process which was range dependent. These stages allowed the pilot to reason if the entity was within a particular range. The availability of additional entity annotations depended on the range at which the entity was approached a designated tracked entity, which resulted in a set of additional entity annotations available to the pilot from the virtual environment which the pilot could access without having to model a detailed perception process. The complete set of labels is listed in Table 1.

The label and annotations that were available to the pilot agent for any given tracked entity depended on how close the fighter aircraft was to the entity. As the fighter aircraft approached a designated tracked entity, more information (or levels of detail) became available. The table indicates the types of labels/annotations that become available to the pilot as he/she goes through four stages of perception (Detection, Classification, Recognition and Identification).

Components such as radars, radar warning receivers and radar jammers all interacted via the radar modality. Similar modalities were also available for other parts of the electromagnetic spectrum. These included visual, infra-red, laser and radio communication modalities of the virtual environment.
5.6 Illustrative Example

In this section we present a simple cut down example that is indicative of the reasoning undertaken by the fighter pilot agent in HAVE. In this example the fighter pilot agent starts with a goal to find enemy tanks within a particular patrol area and destroy them. When the pilot begins the search, the radar is put in to an air-to-ground mode capable of picking up moving ground targets such as vehicles.

1. The fighter pilot observes that the radar can detect a number of ground tracks. The track annotations inform him that they are all vehicles (Class = Vehicle) of some sort.

2. The pilot’s Orient reasoning step informs him that each one of these vehicles affords identification. Associated with each vehicle track is the affordance IDENTIFY.

3. The pilot then decides to stop searching for vehicles and decides to adopt the affordance to IDENTIFY the entity closest in range.

4. The pilot has now adopted a new goal to IDENTIFY for the selected track of interest which results in setting the aircraft heading towards this track, reducing altitude and designating the FLIR sensor onto this target for a closer visual identification.

5. As the fighter flies closer to the track, the track state changes from Detected to Classified to Recognised and ultimately to Identified. The changes of track state indicate that more annotations from the virtual environment become available to the agent through its sensors. As the pilot gets closer to the track of interest he finds out that it is a tank that hasn’t been destroyed, is of a particular type and eventually gets close enough to determine that it is an enemy tank. The Orient step in the agent reasoning model can now determine the the track affords being attacked because it is an enemy tank.

6. The agent then abandons the IDENTIFY goal and adopts the affordance to ATTACK TARGET.

7. The execution of the ATTACK TARGET goal results in the pilot designating the laser onto the specified target and when within weapons range drops a 500-lb laser guided bomb onto the target, in an attempt to destroy it.

Figure 5: A screen capture from the Human Agent Virtual Environment. Visible in the image is a strike fighter aircraft on a CAS mission. A number of annotations are visible on the aircraft as well as two beams, one representing the current range and field of view of the radar, and the other of the forward looking infra red (FLIR) sensor.

Although this is a scaled down example, it does illustrate a viable and interesting application of the concept of affordances for representing action and goal possibilities for a CAS mission in HAVE. Affordance determination is made easier through the use of annotations in the environment, reducing the need for a sophisticated human perceptual model. This is important in military simulations where computational performance is a factor. Furthermore, an affordance based approach to agent design places a greater emphasis on environmental interaction and on the situated nature of agency. This is because the agent designer is required to think about the possible actions and goals that the various entities in the environment afford the agent under different circumstances.

6. OUTCOMES, LESSONS LEARNT AND FUTURE WORK

The development of HAVE was part of a wider research program exploring the interaction between agents and the virtual environments they were situated in, specifically for use in military simulation. Although HAVE was a research concept demonstrator and has not been used operationally, it was however a simulation of a complex and real world domain which resulted in a number of relevant lessons learnt.

These lessons include the importance and viability of having multiple, alternative yet consistent representations of the virtual environment. This means that each type of model, whether it be cognitive (such as an intelligent agent), physical (such as a dynamics or sensor model), or visual (such as a graphical renderer) has available to it a representation of the world that is tailored to the needs of this model. When we are using agent models, this means that the environment can be accessible and amenable to the agents without having to worry about modifying or translating an exist-
ing or legacy environmental representation to make it agent friendly. When combined with an affordance based approach to agent reasoning, the interaction with the environment becomes more central to determining the agent’s behavior, which is consistent with work undertaken in the field of situated cognition [3].

Future work in this area includes the addition of alternative agent architectures in HAVE. Also, alternative affordance based agent architectures will be investigated in more detail, specifically exploring issues such as computational impact of spreading the intelligence computation between agent and environment. Preliminary results from the investigations into different affordance based agent architectures related to HAVE have been submitted for publication in [13].

In the meantime, HAVE will continue to be a vehicle for exploring research issues in agent-virtual environment interaction. There has also been some interest expressed in taking some of the ideas from HAVE and using them in an operational simulation system to be used for large scale operational analysis studies.

7. ADDITIONAL AUTHORS

Clint Heinze (Defence Science and Technology Organisation) and Tim Patterson (Advanced VTOL Technologies).

8. REFERENCES


