DISMOUNTED INFANTRY IN DISTRIBUTED INTERACTIVE SIMULATION

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ABSTRACT

Simulation of dismounted infantry in realistic numbers and behaviors was omitted from SIMNET, the prototype DIS-type simulation. Representation and simulation of dismounted infantry are not obviously fitted into the same framework as vehicles because models of humans are more complicated and not well understood. This paper describes a dismounted infantry simulation system developed at the Institute for Simulation and Training, and reports on lessons learned about simulating dismounted infantry in DIS-type simulations.

IST's Semi-Automated Forces Dismounted Infantry (SAFDI) project developed a Computer Generated Forces system with specialized capabilities for dismounted infantry. The goals of the SAFDI project are twofold: first, to provide a realistic simulation of dismounted infantry for the benefit of SIMNET trainees, and second, to learn about the simulation of dismounted infantry in support of future DIS simulations (like CCTT). The SAFDI system has been installed at training sites and has been used in training scenarios involving US Army soldiers. This paper provides an overview of the SAFDI system, including the project's goals, the system's capabilities, and the results of its evaluation at training sites.

IST's dismounted infantry research has led to a number of lessons learned of general applicability in the area of simulating dismounted infantry in DIS-type simulations, including SIMNET, BDS-D, and CCTT. This paper will address the following questions:

1. Why simulate dismounted infantry in DIS-type scenarios?
2. What are the distinctive characteristics of dismounted infantry that are important to its simulation?
3. How does one simulate dismounted infantry in DIS-type scenarios?
4. What mistakes were made in the design of SIMNET that made retrofitting it with dismounted infantry problematic?
5. How well does the emerging DIS network protocol standard support special requirements of dismounted infantry?

BIOGRAPHIES

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INTRODUCTION

Dismounted infantry (DI) plays a crucial role in battlefield exercises, and is an important requirement for any battlefield training system. According to [O'Byrne,1993], "...the presence of dismounted infantry [is] indispensable on the virtual battlefield." Dismounted infantry soldiers are difficult to detect in the battlefield (they are much smaller than vehicle platforms and therefore have a large number of choices for concealment). However, dismounted infantry are armed with powerful weapons (e.g., Dragon, RPG16, Stinger, SA-7 Grail) and thus are a dangerous threat for enemy vehicle platforms.

For all intents and purposes, SIMNET, the prototype distributed interactive simulation, did not include dismounted infantry. This provided an unrealistic training environment. Vehicle crews moved about the battlefield without concern for hidden and dangerously armed infantry. M2 Bradleys were always considered to be mounted in training exercises and the M2 crews could not learn about appropriate dismount procedures. Since SIMNET was not equipped with DI, it is also an incomplete tool for analysis; it does not allow new tactics or weapons to be tested against DI and does not allow infantry tactics or weapons to be tested at all.

CCTT and future simulations will require dismounted infantry. However, SIMNET provides no opportunity for learning about infantry simulation in distributed interactive simulation. This paper describes one system that retrofitted SIMNET with dismounted infantry and discusses some of the lessons learned about simulating dismounted infantry in distributed interactive simulation (DIS).

This paper is organized into three main sections. First, we will identify some of the characteristics of DI that make it difficult to simulate in a DIS-type simulation. The second section will present the IST Semi-Automated Forces Dismounted Infantry (SAFDI) system. The final section will discuss the SIMNET and the DIS network protocol standards relative to DI simulation.

SIMULATING DI IN DIS

Dismounted Infantry Characteristics

Distributed interactive simulation of dismounted infantry is a difficult problem. Historically, DIS-type simulations have been developed which are able to represent individual ground vehicle platforms with physical dynamics models and behavior models; these models are well described using a relatively small set of data points (location, orientation, turret heading, etc.). However, there are many characteristics particular to dismounted infantry that make their simulation problematic.

Physical characteristics. Because dismounted infantry are humans, their physical characteristics are not easily described with a small number of data points, DI are humans, they are not vehicle platforms. They have many articulated parts, rather than one or two common on ground vehicle platforms.

Behaviors. DI behaviors are more complicated than vehicle behaviors. They involve numerous fine details of posture changes, formation changes, and use of micro-terrain.

Groups. Dismounted soldiers typically work in groups ("fireteams"). The composition and mission of these groups can change dynamically. Some DI behaviors and capabilities apply to the groups, while others to the individual soldiers.

Missions. DI soldiers have different missions. For example, one squad of dismounted infantry soldiers could be assigned as forward observers and armed appropriately; another squad could be assigned in an anti-aircraft capacity and armed with Stinger missiles.

Mounting and dismounting. DI-to-vehicle platform interactions are similar to vehicle-to-vehicle interactions (sighting, target acquisition, firing, etc.), with one important addition: DI have the ability to mount and dismount vehicles. Mounting and dismounting are surprisingly complicated operations if implemented in full detail. Some details that can be included are the number of soldiers that can fit into a particular vehicle (such as an M2 Bradley Infantry Fighting Vehicle), the amount of time it takes for the soldiers to enter or leave the vehicle, the locations for mounting and dismounting to take place relative to the vehicle, how to handle situations when more soldiers are trying to mount a vehicle than can fit, and how to handle situations when the vehicle absolutely must move during mounting or dismounting.

Weapons. DI soldiers can use many different weapons. These weapons may be transferred between soldiers and can be dropped and picked up later.

Types of DI Simulation Systems

A further complication of dismounted infantry simulation is the purpose that dismounted infantry are to serve in the exercise. There are two types of dismounted infantry simulations: *DI generators* and *DI trainers* [Petty, 1994].

DI generators provide dismounted infantry to the distributed interactive simulation for the benefit of other participants. For example, vehicle crew training requires large numbers of dismounted infantry soldiers that are capable of a relatively small number of behaviors (see discussion of the SAFDI system below for example behaviors). Typically, generated DI are controlled by operators who are part of the simulation, not by the trainees taking part in the simulation; a single operator often controls more than one DI entity. DI generators provide entities at the squad or fireteam level.

In contrast, DI trainers are intended to train humans in DI skills by involving them in the battlefield simulation. In this case, the fidelity of the simulation is very important for the simulation operator, since that person is being trained. Team leader training requires a much higher resolution model of physical and behavioral characteristics to be effective. In this case, DI entities represent individuals in the battlefield simulation.

At this stage of dismounted infantry simulation development, DI generators do not act as DI trainers and vice-versa. The reason for this lies in the tradeoff between the number of DI entities that can be supported and simulation fidelity; effective DI generators handle many more entities than DI trainers, but DI trainers have much better fidelity than DI generators. Therefore, the choice between these two simulation types drastically affects the architecture of the dismounted infantry simulation system.

THE SAFDI SYSTEM

Overview

In order to address the limitations of the original implementation of dismounted infantry in SIMNET and to learn about how to simulate dismounted infantry in DIS-type simulations, STRICOM asked the Institute for Simulation and Training (IST) to extend its Computer Generated Forces (CGF) Testbed to simulate dismounted infantry. The resulting extension and specialization of the Testbed is known as the Semi-Automated Forces Dismounted Infantry (SAFDI) system. More information about SAFDI can be found in [Franceschini, 1994]. The SAFDI system is an example of a DI generator.

Like the CGF Testbed upon which it is based, the SAFDI system is composed of two types of components: Simulators and Operator Interfaces. A Simulator consists of a personal computer and IST-developed software that generates and simulates dismounted infantry fireteams. An Operator Interface is a separate PC and software system through which a human operator issues commands and instructions to the Simulator. The Simulator, in turn, is responsible for carrying out those commands within the simulated environment.

Project Goals

Initially the SAFDI project had two goals. First, SAFDI served as a demonstration and test application for the IST CGF Testbed. Second, the SAFDI project demonstrated the feasibility for adding a cost effective dismounted infantry CGF component to a DIS battlefield and to future networked simulations. It is important to note that the SAFDI system was developed in support of training vehicle crews in SIMNET; it was not designed to be a trainer for dismounted infantry.

The project's success at meeting its initial goals resulted in an expansion of the work and three new goals: first, to provide a stable CGF dismounted infantry system for evaluation at SIMNET/BDS-D sites; second, to develop dismounted infantry capabilities in a CGF system; third, to build up experience in using dismounted infantry in a DIS-type simulation. The last goal has grown in importance over time.

Basic Capabilities

In the battlefield, entities generated by the SAFDI system have a substantial set of basic capabilities. They can:

- Sight activity within Line of Sight
- Report sightings to an operator via the Operator Interface
- Kill enemy infantry and vehicles using small arms or missiles
- Mount and dismount vehicles
- Be seen according to visual range and posture
- Be killed by hostile direct and indirect fire
- Change visual appearance based on posture
- Change movement speed

In addition to fireteams, the SAFDI system can generate and control certain types of vehicles closely associated with infantry; specifically, the SAFDI system can generate Soviet-made BMP and US M2 Bradley Fighting Vehicles (BMPs/BFVs) and Soviet-made T-72 and US M1 tanks. SAFDI vehicles have capabilities similar to those of the SAFDI fireteams: they can move, detect enemy entities, report sightings, fire weapons, and be destroyed. In addition, SAFDI BMPs/BFVs can transport SAFDI fireteams. BMPs/BFVs may be used in support of SAFDI fireteams or independently to flesh out a detachment of simulators in an exercise.

Advanced Capabilities

System parameter files. There are several configuration files that affect the SAFDI system. These files contain information that controls the SAFDI simulation. They are useful for playing "what if" scenarios and for scaling the proficiency of SAFDI entities. The following is a partial list of the values that are controlled through the configuration files:

- Probability that a fired round will hit an entity
- Probability of a kill
- Amount of damage suffered by an entity when hit by a particular round
- Sighting distances
- DI mount/dismount time
- Physical specification for entities (maximum speed, maximum amount of ammunition and missiles, location of weapons, etc.)
- Missile dynamics (initial speed, acceleration, maximum flight speed, etc.)
- Parametric fireteam configuration information (see description of parametric fireteams below)

SAFDI configuration files only affect the abilities of SAFDI entities; no other entities are affected.

The configuration files are plain text files. They can be modified with any text editor. The file format is designed to be easy to modify by site support personnel. Parameter values are completely described in the documentation accompanying the SAFDI system.

Group commands. SAFDI entities on one workstation can be grouped together in a command hierarchy (see Figure 1). This allows the operator to command many SAFDI entities with a single order, which makes it easier to use the system. Some commands that may be issued to groups include giving permission to fire; posture, speed, and heading changes; mount and dismount; and routing. Giving an order to a group is similar to giving an order to each individual member of the group, one at a time.

A group can be included as a member of another group. One application of this feature is to group SAFDI entities into different platoons, and then put the platoon groups into a single company group; this way, either the entire company or any platoon will receive a command while only one operator command was issued.

The SAFDI operator can give orders to an individual SAFDI entity even if the entity is part of a group. For example, a group could be commanded to route to a location two kilometers away; one tank in the group could be told to halt while the rest of the group continues on the route.

Attach and follow. A SAFDI entity can be ordered to attach to any simulated entity; the attached to entity becomes the leader of the SAFDI entity. When a SAFDI entity is attached to a leader, it will follow the leader when the leader moves. This capability operates by matching speed and direction; it does not attempt to preserve formations. It is intended to allow SAFDI DI to follow manned simulators or SAFDI infantry fighting vehicles.

Attach and Follow is useful in conjunction with the Fire When capability (which automatically gives an entity permission to fire when a specified entity fires). The combination of these two features provides a means to give tactical information to SAFDI entities, as follows. SAFDI entities can be ordered to Attach and Follow and Fire When a human-controlled entity (for example, a manned M2 simulator). The human-controlled entity makes tactical decisions which are mimicked by the SAFDI entity automatically.

New infantry icons for CIGs. A significant part of the hardware of manned tank simulators and Stealth devices is the computer image generator (CIG) for displaying a three-dimensional out-the-window view of the battlefield. As a result of the first design for fireteams,

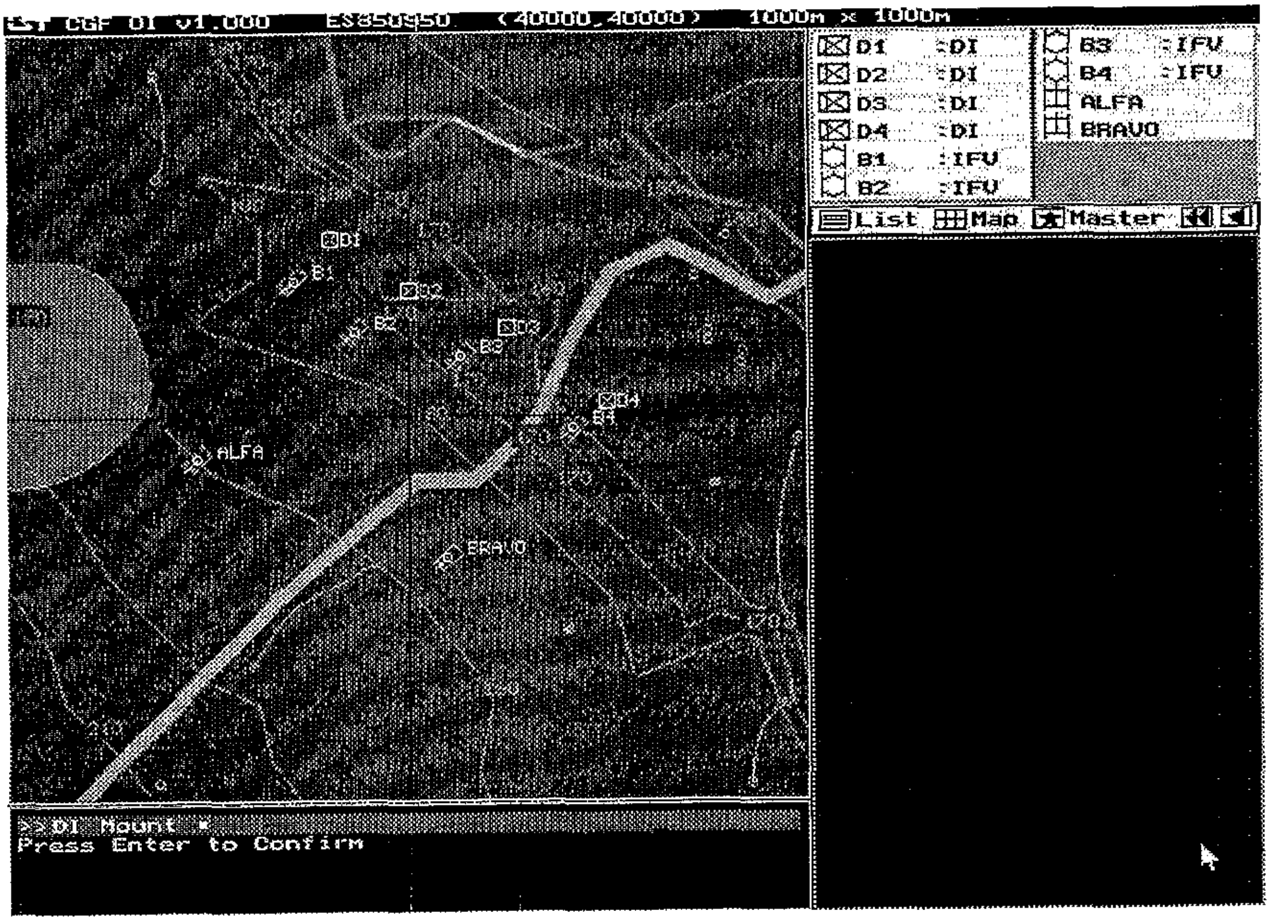

Figure 1 – Group Commands in SAFDI

the original SIMNET CIGs displayed one icon for each fireteam (group of five soldiers). This icon was composed of two perpendicular polygons with the picture of a soldier painted on each plane.

As part of the SAFDI development, IST created new visual icons for fireteams to be used in these devices. SAFDI's icons are compatible with SIMNET CIGs, and have been installed on the Stealth and manned M1 simulator at IST. These polygonal icons can be adapted to other CIGs. SAFDI will correctly use either the new IST developed icons or the standard icons; this can be controlled through the configuration files.

IST's new icons are three-dimensional human models with separate polygons for the head, arms, torso, legs, and weapons. The icons vary with alignment, posture changes, and weapon types. Some examples of the new icons include a sitting (kneeling) figure with a Dragon launcher, a standing figure with a shoulder SAM launcher, and a forward observer with field glasses.

In conjunction with the parametric fireteam capability (described below), IST developed the capability to use one icon to represent one soldier in the out-the-window CIG view. Each soldier is represented by an icon appropriate to the soldier's weapons, posture, and activity (e.g., whether the soldier is about to fire at a target). The SAFDI system automatically determines the appropriate icons to display for each soldier and sends the appropriate PDUs to other networked simulators.

Air defense weapons. SAFDI allows soldiers in a fireteam to use surface-to-air missiles. The missiles implemented are the Stinger and the SA-7 Grail. Air targets are prioritized based on whether their primary function is to engage targets from air to ground or from air to air. Within each of these divisions, rotary wing craft have higher priority than fixed wing craft.

Forward observers. SAFDI fireteams can be configured to include Forward Observers (FOs). FOs scan the terrain for enemy targets. When they acquire valid targets, FOs autonomously request indirect fire from the SAFDI system at the locations of the targets.

Parametric fireteams. Parametric fireteams allow specialized infantry to be used in battles. Rather than providing a fixed fireteam configuration, the SAFDI system allows the user to determine the make up of a fireteam in terms of the number of soldiers and the weapon types carried by each soldier.

In the SAFDI system, a DI entity represents a fireteam. Fireteams consist of one to six soldiers and are configured by the SAFDI operator or site personnel. Each soldier potentially carries an anti-tank missile (ATM), surface-to-air missile (SAM), squad automatic weapon (SAW), Grenade launcher, or rifle.

For example, a fireteam might consist of

3x Riflemen
1x SAW gunner
1x ATM gunner

Multiple fireteam compositions can be simultaneously defined and used by the operator. The definitions of fireteams are contained in the system parameter files (described earlier).

This representation of fireteams allows certain behaviors to be associated with the aggregate fireteam while other behaviors are associated with the individual soldiers. This allows computationally intensive operations (e.g., intervisibility calculations or routing) to be performed on the fireteam as a whole, but still allows certain operations to be performed for individuals (e.g., posture settings or firing weapons).

Soldiers within SAFDI fireteams are assessed damage as individuals rather than as an aggregate. Specific damage and suppression results are probabilistically calculated for each member of the fireteam when attacked. These results are associated with the particular soldier and remembered for future attacks.

In SAFDI, there is currently no simulation of wounding individuals; individuals are either alive or killed.

Delivery and evaluation. IST delivered the SAFDI system to SIMNET sites in two phases: the Basic and Enhanced SAFDI systems. The Basic SAFDI system was delivered during September 1993 while the Enhanced SAFDI system was delivered during February 1994. At each delivery, IST installed the SAFDI system on the site's computers, gave a capabilities demonstration, and conducted operator and support personnel training.

After delivery, the SAFDI system was evaluated at the Ft. Benning training site by a team of site personnel and simulation experts. The evaluation consisted of a series of training scenarios where A Company 1/29 Infantry fought with and against dismounted infantry generated by the SAFDI system. During the evaluation, the SAFDI system was operated by the evaluators, rather than IST personnel.

The results of the evaluation are discussed in [D'Errico,1994]. In general, the evaluators found many opportunities for improvement in the SAFDI system, but overall were very pleased with the system's performance and the realism added to the simulated battlefield. Captain William Hessenius, commander of A Company, said, "SAFDI greatly increased my unit's training" [D'Errico,1994].

Here, we summarize some of IST's observations from the evaluation of the Basic SAFDI system (IST has not observed the evaluation of the Enhanced SAFDI system).

SAFDI was completely reliable throughout the evaluation; it ran for a total of approximately 16 hours in three training scenarios without crashing even once. This is especially impressive considering that one of the scenarios contained over 120 entities (which is three times SAFDI's rated capacity). In comparison, the production site semi-automated forces system crashed three times during evaluations.

When dismounted infantry were added to the simulation, the pace of battle slowed dramatically. In one instance, Fort Benning's site personnel estimated that one of the scenarios would have taken about 35 minutes to complete without dismounted elements; that scenario took two hours with DI.

SAFDI entities participated realistically in the battles. They engaged enemy targets, mounted and dismounted friendly infantry fighting vehicles, etc.

BATTLEFIELD NETWORK PROTOCOLS AND DISMOUNTED INFANTRY

DI in SIMNET

The original SIMNET implementation had some idiosyncrasies that made retrofitting it with dismounted infantry difficult. These SIMNET problems are listed in order to avoid making the same mistakes in future network protocols like DIS.

One icon per fireteam. In SIMNET, the standard dismounted infantry entity represents a fireteam. This fireteam consists of five soldiers, but is rendered by the SIMNET image generators as a single icon depicting a single soldier. Therefore, there is no visual cue to a battlefield observer to indicate the number of soldiers in the fireteam that are capable of fighting. In the evaluation of the Basic SAFDI system, the soldiers identified this as the worst feature of the simulation (note that this was an inherent problem in SIMNET; as mentioned earlier, IST has developed an experimental solution to this problem) [D'Errico,1994].

No mount or dismount procedures. Although SIMNET is equipped with a Dismounted Infantry Module (DIM) that can mount and dismount vehicles, there is no formal exchange of information on the network when a mount or dismount takes place; mounting and dismounting are not included in the SIMNET protocol. Therefore, vehicle crews have no easy way of knowing when mounting or dismounting is taking place (in an early version of SAFDI, the dismounted infantry fireteam was positioned in front of the manned simulator during mounting so that it could be seen through the vision blocks of the vehicle crew). Furthermore, there is no protocol in SIMNET for determining whether a vehicle is mounted.

No coaxial machine guns on simulators. Coaxial machine guns are the weapon of choice for ground vehicle platforms against dismounted infantry. However, standard SIMNET manned simulators (e.g., M1 and M2) are not equipped with coaxial machine guns. Therefore, dismounted infantry can be engaged in one of three ways in SIMNET by vehicle crews: by radioing for artillery support, by colliding with the dismounted infantry, or by using a non-standard weapon (such as the main gun) against a fireteam. While the first two cases are acceptable in terms of battlefield realism, the third case is not; one could argue that this situation has a negative training effect.

DI in DIS

While the existing DIS standard has a mechanism for representing small dismounted infantry units, this mechanism is crude and is really only an afterthought to the primary goal of representing tanks and other vehicles. This section discusses several specific limitations of DIS for DI: the lack detailed entity state information for life forms; the limited representation of objects; the lack of detail in small arms firing events; and the lack of dynamic terrain.

Life form state representation. The DIS specification (version 2.0.4 [IST,1994a]) attempts to classify many types of life form entities, but the classifications in the entity type record are inappropriate. The first problem is that aspects of entity *activity* or *appearance* are used as *type* characteristics. For example, parachutists, dismounted infantry, and swimmers are separate types. The same entity could take on all three roles during an exercise, requiring that its type change. These particular actions are in fact duplicated in the life form appearance record! The second problem is that the type record determines the type of the entity from the weapon it is carrying. Entity types should not be tied to such objects, which the entity may drop, pick up, or exchange in the scenario. Furthermore, most DI entities will carry more than one weapon; the entity type is then ambiguous.

The DIS appearance record for life forms allows for prone, kneeling, and upright states; and for crawling, walking, running, and jumping "gaits." This limited set of states is not adequate for simulations that allow close inspection of the entity, such as individual-level simulations. In an individual-level simulation, many other states are also desirable—leaning around a corner, crouching below cover, twisting the body or head to look or direct a weapon in a different direction than the feet are pointing, etc. Simulations will also soon require explicit communication between soldiers; at the individual level, this is often done with arm signals. Thus detailed arm positions may have to be included in the soldier representation.

The need for detailed state representation for body position leads to questions about how the overall DIS design will scale up when used for individual combatants or other high-resolution DI exercises. The detailed representation requires a much higher bandwidth than is usual for vehicles or aggregate entities. Not only does this requirement load the network, but all other entities must process the high-resolution state information. The bandwidth requirement could possibly be reduced by using "intelligent" dead-reckoning algorithms that can generate detailed body movement from abstract "task" descriptions; soldier tasks would presumably change far less often than joint angles. Furthermore, entities that don't need detailed state information can omit the reconstruction of detailed posture. However, this approach has the problem that the dead-reckoned reconstruction of entity movements may not correlate well enough with the actual entity movements. The dead-reckoned movements may also lag the actual movements, since the task abstraction in effect low-pass filters the entity movements. These errors could be crucial when sighting and firing opportunities pass quickly.

Object representation. The representation of objects in DIS is essentially limited to entities. Having representations for other objects would be useful in general, but is especially needed for DI. Fireteams (and even individual soldiers) typically carry many pieces of equipment and weapons that they use in combat. They carry ammunition for themselves and squad weapons, pieces of squad weapons, grenades, etc. These objects are held in different positions, used, stowed, expended, dropped, picked up, put in other objects, and given to other soldiers. The Destructible Entity protocol in DIS version 3.0 [IST,1994b] would be awkward to use for objects because they may change state frequently. A new component must be added to DIS to represent such objects.

Weapons fire. Weapons fire is represented in DIS with a Fire PDU followed by a Detonation PDU. Each of these can indicate in a Burst Descriptor that the event contained multiple rounds. However, there is no provision to indicate where each round went. This limitation is not acceptable in a detailed simulation with DI because each round may be significant (especially at the individual level). In addition to normal scatter from weapon movement, rounds may ricochet and cause multiple impacts. At the very least, the Fire PDU should indicate a standard scatter pattern.

In addition to impact locations, DI simulations also need to compute munition trajectories (at least roughly) because soldiers hear the rounds passing by even if they don't impact nearby. The trajectories cannot always be computed from impact locations because rounds may leave the terrain database before impacting. Fire PDUs must therefore provide basic trajectory information.

Finally, the life form appearance record allows for weapons to be stowed, deployed, and in the firing position. However, there are no definitions associated with these states, and at any rate three states may not be sufficient. A rifle, for example, could be slung on the soldier's back in one of several ways, held in one hand several ways, held with both hands several ways (e.g., down, level at waist, at chest level, across the arms, at eye level, pointing up, etc.), held in a sling, etc. These postures may be important for determining a soldier's status, activity, or intentions.

Dynamic terrain. As with objects, dynamic terrain will eventually be useful for all domains of DIS simulation. Dynamic terrain will be crucial to detailed DI simulations because the soldiers interact with the environment to such a great degree. In fact, at the individual level the distinction between objects (which presumably can be moved during a simulation) and terrain features is fuzzy. Rocks, trees, debris, doors, windows, etc. are part of the terrain, but can all be moved, changed, avoided, jumped, used for cover, etc. by soldiers. The current DIS design does not have an adequate mechanism for representing dynamic terrain.

The solutions to most of these problems seem to require increased computation and increased network bandwidth. We are attempting to develop solutions that will allow the DIS simulators to provide an adequate environment for training while limiting the increase in performance required in the system.

CONCLUSIONS

Dismounted infantry soldiers are more difficult to represent in distributed interactive simulations than most of the vehicle platforms typically involved in DIS-type exercises. However, they provide a key component which dramatically affects tactics in the battlefield. Therefore, their inclusion in distributed interactive simulations is crucial to successful future training and analysis.

This paper has outlined the issues involved in representing dismounted infantry in distributed interactive simulations. Dismounted infantry pose a technical challenge to DIS-type exercises for two reasons: human models are inherently complicated and the simulation community continues to think of new ways that human models should be used. Models of dismounted infantry that are used as the basis for future network protocols must include some method of being simple but extensible.

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