Sides, Force, and ROE for Asymmetric Environments

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ABSTRACT

Combat simulations have typically used the simplifying assumption that combatants wear uniforms expressing their allegiance and their vehicles are appropriately marked. In Distributed Interactive Simulation (DIS) and its High Level Architecture (HLA) derivatives, this is represented by the force attribute: friendly, opposing, or neutral. Rules of Engagement (ROE) are restricted to the friendly side shooting the opposing side and vice versa. In today's asymmetric urban combat environments, this simplifying assumption is no longer valid. A common workaround has been to represent insurgents as neutral until they expose their weapons, at which time they switch their force attribute to opposing. However, the utility of this approach is limited, especially in cultures where weapons and militias are common. At the USJFCOM Joint Futures Laboratory, we are developing a new representation of sides and ROE for modeling asymmetric environments. We have incorporated a multiple sides representation and we differentiate between true allegiance and the uniforms or markings of the simulated entities. Other allegiances such as religion and tribe are captured with additional attributes. Simulated asymmetric opponents can attack as civilians or even as a side allied with the U.S. making ROE significantly more complicated. Now ROE and target acquisition have to deal with the recognition of aggression followed by the tracking and potential reacquisition of the perpetrators in a crowded environment. Fortunately, a number of experiments that study people's ability to perform these tasks are being conducted and models are being developed from them. The challenge of incorporating these more detailed models of target acquisition and ROE into urban combat simulations is exacerbated by the common use of force as a filter to support scalability, assuming that the friendly force only needs to monitor the opposing force and vice versa. Without that assumption new approaches are needed to deal with dense urban populations.

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INTRODUCTION

Under the Distributed Interactive Simulation (DIS) standard (IEEE, 1995, 1998), the allegiance of agents in a simulation is determined by the force attribute, which can take on the values of friendly, opposing, or neutral[1]. This has been preserved in High Level Architecture (HLA) simulations using the Realtime Platform Reference Federation Object Model (SISO, 1999) and it is commonly used as the primary driver for engagement decisions. It is a useful abstraction as long as the rules of conventional warfare, where combatants are identifiable by their uniforms and vehicle markings, are followed. However, our current enemies have discarded these rules and are employing irregular forces, who blend into the local population and use them for concealment and sometimes cover. This gains them an asymmetric advantage over our troops who can be easily identified and targeted.

At the Joint Forces Command (JFCOM) Joint Futures Laboratory, we are conducting simulation experiments aimed at improving our conduct of operations in asymmetric urban environments (Ceranowicz and Torpey, 2004). The need for more flexibility in our modeling of irregular forces has led us to depart from the DIS standard and start investigating alternative representations.

REPRESENTING IRREGULARS

In previous experiments we have used the force attribute with several workarounds to represent and identify insurgents. Insurgents were assigned a force attribute of neutral so that they match the civilians in the area. Following an approach used in DISAF[2], the value of the insurgents' force attributes were then changed to opposing whenever they exposed their weapons or engaged in visibly suspicious activities. This allowed the friendly forces to use traditional engagement logic against them. Once the weapons were hidden and the suspicious activity was concluded, the force attribute was reset to neutral. For modeling reconnaissance sensors such as those on Unmanned Aerial Vehicles (UAVs), we ignored the force attribute and used the entity type enumeration, from the DIS enumeration standard (SISO, 2006), in conjunction with appearance and activity attributes to determine if the target was hostile. These two approaches are actually very similar. Many entity enumerations are specific to a particular force and while the first approach monitors the force attribute to detect hostility, the second monitors the PrimaryWeaponState attribute. The first approach is used in the Joint Semi-Automated Forces simulation (JSAF) and the latter in the Simulation of the Location and Attack of Mobile Enemy Missiles (SLAMEM).

While these approaches were adequate for our previous experiments, they have significant limitations. In the JSAF approach where the force attribute is dynamically modified, it is assumed that everyone with a sensor able to identify the target will also be able to determine whether the target is committing a hostile act. However, the determination of hostility may require the identification of the objects the target is carrying and its activities. This may require additional resolution or tracking time and the amount will vary depending on the objects and activities involved. For example, a rifle will be more prominent than a grenade. Changing force treats all hostile acts and sensors equally. Another problem with the approach of dynamically changing force is that the entity loses its sense of identity. Its targeting and reactions are based on its own force attribute so it must act as a friendly entity until set to the opposing mode by operator input. This loss of identity also affected the experiment and opposing force controllers, who still wanted to be able to identify who the insurgents were and track their movements.

For future experiments we decided to start evolving the representation of entity allegiance. We retained force for backward compatibility with other simulations

[1] The latest version of the DIS enumerations has expanded the force enumerations to include friendly*i*, opposing*i*, neutral*i* where $i = 2,\ldots,10$

[2] Dismounted Infantry Semi-Automated Forces

utilizing the DIS standard. We added two additional attributes: side and projected_side. Side indicates the true allegiance of the entity while projected_side indicates what the entity allegiance appears to be based on its uniform, markings, or other visible features. So a conventional entity would have its side equal to its projected_side, while an insurgent would have different values for its side and projected_side. The value of the projected_side would change if, for example, the insurgents were to exchange their civilian clothes for army uniforms. The side attribute would only change if the insurgents had a change of heart and actually switched their allegiance.

Both side and projected_side take on the same range of values. Rather than creating a static set of side values, it was decided that they would be defined as part of the scenario. An example of potential sides and relationships is shown in Table 1. The table organizes the sides conventionally with two sides friendly to the U.S., five enemy sides, and two neutral sides. It is also possible to define asymmetric relationships such as two friendly sides, where one is friendly to a third group and the other is the enemy of the third group. It is even possible to have one group perceive another as friendly even though the other perceives it as an enemy. The relationships can also be changed dynamically.

	US	Iraqi Police	Iraqi Military	Neo Baathist	Criminal	Foreign Insurgent	Jihadist	Militia	Civilian	NGO
US		F	F	O	O	O	O	O	N	N
Iraqi Police	F		F	O	O	O	O	O	N	N
Iraqi Military	F	F		O	O	O	O	O	N	N
Neo Baathist	O	O	O		F	F	F	F	N	N
Criminal	O	O	O	F		F	F	F	N	N
Foreign Insurgent	O	O	O	F	F		F	F	N	N
Jihadist	O	O	O	F	F	F		F	N	N
Militia	O	O	O	F	F	F	F		N	N
Civilian	N	N	N	N	N	N	N	N		N
NGO	N	N	N	N	N	N	N	N	N	

Table 1. UR2015 Sides and Relationships
F–Friendly, O–Opposing, N–Neutral

In addition to the side and projected_side, additional attributes express finer distinctions within a side. For example, a service attribute is used to distinguish Army, Navy, Air Force, and Marine entities.

An entity's force attribute value is effectively derived from the relationship between the U.S. and the entity's projected_side. Thus the first row of Table 1. gives the force attribute for any entity with that projected_side. This retains compatibility with other simulations which still rely on the force attribute.

ROE

Rules of Engagement (ROE) as modeled in JSAF and other Semi-Automated Forces simulations assume that you have identified an entity as hostile via the force attribute. Then the ROE specifies when an entity should shoot at a target entity:

- Hold – never shoot
- Tight – shoot if fired on
- Free – shoot on sight.

You can also specify which enemy entity types you will engage and in what order.

An important flaw in this model of ROE is the assumption that no force would ever target and fire on neutral or friendly parties or those from their own side. This became an issue in experiments where it was desired for the opposing forces to kill civilians and when insurgents are spotted committing hostile acts but subsequently go back to appearing neutral. We worked around these issues by creating an editor that would allow an operator to have an entity shoot at another entity irrespective of side. However, this approach was limited since the operator had to manually initiate each round fired on the target entity.

With this new representation of sides and their relationships, we needed to redesign the JSAF ROE code to utilize the side and projected_side attribute information. We performed an analysis of the potential requirements for ROE. The traditional use of ROE is for automatic firing upon the identification of an entity whose side has an opposing relationship with your side. However, this is just the beginning of potential automated engagement criteria. We would like to be able to order an agent to engage entities based on a wide range of criteria including targets:

1. whose projected side is hostile to the agent's;
2. which are firing at the agent;
3. with a specific ID (this would correspond to facial recognition);

4. that satisfy a general description (a target is spotted running away from the scene of assassination and a good description of him has been broadcast);
5. located in a restricted area or one known to be only occupied by valid targets;
6. attacking other entities belonging to the agent's side or an allied side;
7. attacking neutral entities;
8. attacking the agent's unit;
9. carrying certain types of weapons;
10. who do not respond to warnings and orders;
11. which satisfy some combination of the above criteria.

The first criterion and the combination of the first and second are those that we have traditionally supported. To reimplement them we created a utility function that would evaluate the side of the entity and the projected_side of the target and return whether the target was friendly, opposing, or neutral as well as whether the target was firing at us. Essentially this function isolated the targeting code from the new sides structure and returned the same information that was provided by the old force information. The difference is that entities can now disguise themselves as belonging to another side without losing their identities. An additional engagement criterion was implemented to allow an entity to shoot at any target it did not consider friendly. This allowed us to model automated shooting of neutral targets.

However, when first implemented, these new capabilities did lead to some unexpected and amusing consequences. When foreign insurgents were first disguised as Iraqi police, they saw the other members of their group as Iraqi police so they drew their weapons and started shooting each other. The targeting code had to be changed to prevent insurgents from targeting their own teams and to prevent them from attacking opposing forces prematurely. We have not yet developed code to recognize aggression and support the additional engagement criteria so for the time being we essentially continue to reveal agents' true sides when they expose their weapons or conduct suspicious activity.

HOSTILITY

In the absence of unequivocal side information, many of the attack criteria listed above depend on recognizing hostile or suspicious activity. JSAF units have long monitored detonations to determine when they are being fired on so they can support the tight mode of ROE, where they cannot fire unless fired on first. However, this capability needs to be expanded to detect hostility to those outside your immediate unit, to others on your side, or on an allied side, or even to neutrals. We also need to generalize the signs of hostility to those supporting the attacker and to more actions than just shooting. Planting explosive devices, directing hostile fire, sneaking into attack positions, or driving a speeding vehicle toward a check point don't involve a detonation but are indicative of hostile intent.

Recognizing and representing aggression is a complex problem. It relies on the actions of simulation agents and on the things they are carrying. Carrying an exposed weapon while projecting a neutral side in the simulation is currently considered a confirmation of insurgent status. But in countries such as Iraq and Afghanistan where the population has been become accustomed to carrying firearms and local militias are prevalent, carrying a weapon is an indicator of a hostile agent but certainly not a confirmation. A system is needed that will represent and recognize not only the objects that an agent is carrying but also the activities in which he is engaged.

ENTITY REPRESENTATION

In order to model the recognition of an agent's activities and the objects he is using, there needs to be a representation of those objects and behaviors in the simulation. Furthermore, there needs to be a representation of neutral objects and behaviors to avoid creating a simulation where just carrying an object is a indication of hostility. Under the DIS paradigm, which is still very widely used in entity level military simulations, objects such as weapons, binoculars, radios, and backpacks are considered to be part of an entity rather than separate objects. Typically, representing an object on the network is relatively expensive in bandwidth and processing so there is incentive to minimize the number of objects. The entity type encoding for life forms allows for one weapon to be included in the enumeration. This is typically the entity’s primary weapon. Appearance bits indicate whether the weapon is present, stowed, deployed, or in firing position. Additional indications of attack in the simulation are the weapon fire interaction which indicates firing cues and the munition detonation which indicates rounds impacting or exploding. Together with the entity's movements and posture, these provide the current simulation cues for detecting hostile actions.

In the past we have had to expand such cues in several ways. Typically an entity type enumeration is static throughout a scenario run, implying that the entity only uses one weapon throughout the simulation and never puts it down. However, insurgents often preposition their weapons, such as mortars and missile launchers, in locations near their planned attack sites. That way they can deploy and use those weapons with the minimum chance of being detected with them. Thus, man portable rockets and mortars were added to the simulation as separate objects and a way was provided for the insurgents to pick the weapons up, emplace and fire them, and then hide them. In these cases, detection of the hostile act would require the association of the person with a nearby weapon object. Fortunately, mortar and rocket attacks are relatively few so representing them as individual objects is tractable, whereas representing every rifle in a large city as a separate object would be prohibitive.

We have also attempted to represent activities explicitly via a set of three attributes: event, mission, and mission_phase. The mission attribute indicates what type of mission the entity is engaged in, such as an IED attack or a mortar attack. The mission_phase attribute breaks the mission out into parts, such as ingress, deployment of the weapon, and attack. The event attribute distinguishes different missions of the same type.

While this representation was initially added for post experiment analysis of the effects of US actions on enemy missions, SLAMEM took advantage of this information to drive a recognition model for suspicious activity. A set of reportable activities was selected including a generic neutral activity. Then a probability table, called a confusion matrix, was derived for the chance that the observation of one activity would result in a report of each of the activities. So when a sensor detects a target performing a particular activity, SLAMEM stochastically samples the confusion matrix to decide which of the activities will be reported. The capability to mistake a hostile action as a neutral action and vice versa should be an essential part of any model driving engagement decisions. The biggest drawbacks of this attempt at recognizing activities were the additional effort required from the operators to maintain the activity information and the fact that the mission phases were not selected to represent detectable events. Significant effort was required to maintain the activity information because most activities of interest are not represented explicitly in the simulation; rather operators combine primitives to create them and then they have to annotate the primitives with the mission they represent. For the purposes of detecting visibly hostile behavior, the behaviors are more limited and we should be able to automate the setting of appropriate behavior attributes.

One aspect of aggressive behavior that is not covered by the enumerated behavior approach described above is the target of the aggressive behavior. If you see two people fighting and you can identify the side of one of them, then you can logically decide which person to help. So in addition to having one or more attributes indicating what sort of aggressive activity an agent is engaging in and perhaps how intense it is, we need an attribute which tells us whom the aggression is being directed at.

It is also important to consider the two alternatives for representing behaviors in a simulation: implicit and explicit. The approach being discussed above is the explicit expression of behavior. Potential behaviors are abstracted into a finite number of behavior classes and the current behavior's class is represented symbolically as an enumerated attribute. Currently the behaviors in most DIS style simulations are expressed implicitly. You have to determine that an agent is reconnoitering an attack site by watching where he goes, what he looks at, whether he takes pictures or movies of the site, and how much time he spends there. An attack is indicated by pulling out a weapon, pointing it at the target, and firing. However, the level of behavioral resolution in most DIS style simulations is insufficient to support recognition of many behaviors and it would be extremely expensive to add such a capability. It requires that the movements of the agent's limbs and body be animated and published and that objects such as cameras and handguns and their position and orientation be explicitly represented. Considering that the average rendering time of one frame of a modern computer animated movie is around seventeen hours, the computational burden is enormous. Even if the computational problem was solved and a person could look at the result and easily recognize the behavior, it would be an even harder problem to develop a program to perform automated behavior identification based on those pictures. Thus the only practical approach to implementing simulated behavior recognition is to explicitly present the behavioral stimulus to the sensor model.

Another engagement requirement is to be able to describe an insurgent and then recognize him by means of some distinguishing characteristic. Modeling facial recognition can be fairly straightforward, each entity has a unique ID and with appropriate resolution on the target, the simulation can compare the ID of the target with that of the wanted man. More generic descriptions however, are a problem in a simulation were there are thousands of entities with the same entity type enumeration. Initially, we attempted to differentiate vehicles in the simulation by assigning them colors and manufacturers via expanded entity type enumerations, but the resulting combinatorial explosion convinced us that we should use another approach. Additionally, it did not seem advantageous to use individual attributes for such rarely changing information. Thus a bit vector attribute similar to the DIS appearance bits was adopted. This is called a trait attribute and each trait is allocated just enough bits to represent its range of enumerated values. Then the traits are packed together into the trait attribute value. We are currently using traits to represent vehicle colors, gender, religion, ethnicity, social status and a few other parameters. This allows us to call for protesting crowds with appropriate cultural backgrounds and in the future will allow us to generate descriptions of entities. Many of these traits are generated statistically to fulfill the population distribution of the area of interest. However, rules are required to make sure that the conditional dependencies between traits and other attributes are maintained. For example, having Sunni members of a Shiite militia should be avoided.

Additional attributes to indicate what a person is holding in his hands and what other equipment an agent is carrying can easily be added to the simulation. Although it is not advantageous to track every rifle and pistol in a large city, making assumptions about where people can obtain weapons when they are planning attacks can make this a manageable problem. We also need to consider items such as video cameras as important clues since insurgents often video tape their attacks. Once these items are represented in the simulation and linked with the appropriate behaviors, we can start to recognize opposing entities by their actions instead of relying on changing their projected_side.

SENSOR MODELING

The use of the force attribute to indicate allegiance and an entity type enumeration to indicate a fixed entity type considerably simplifies sensor modeling. JSAF visual sensor modeling uses a derivative of the Army Night Vision and Electronic Sensors Directorate's (NVESD) Acquire model (Friedmand, et al. 1989; O'Kane, et al. 1992). Based on a characteristic dimension computed for each entity type and a contrast value for the scene, a time to detect and identify a target is drawn. If the target remains in view for a sufficient time it is considered identified. Once identified, the entity's force is considered known and the ROE module will disregard any friendly or neutral entities when deciding whom to engage.

With insurgent combatants, force or projected_side attributes are no longer conclusive for determining whom to engage and the entity's sensors must return additional cues such as if the target is carrying a weapon and if the target is employing the weapon to attack or threaten friendly or neutral parties. Each of these sensory tasks may have a different resolution requirement and difficulty. In addition, the time required for the recognition of an activity may be significantly different than the time it takes to pick out an object from a background. NVESD has revised the acquisition levels and observables for human targets and urban operations (Self, et al. 2005) and is conducting experiments to derive new criteria for applying the Acquire model to the recognition of hand held items and the recognition of hostile activity (O'Connor, et al. 1998; Moyer, et al. 2003; Moyer, et al. 2004). As the results of these studies are processed, they will be incorporated into JSAF to provide a more realistic model of insurgent combat in urban environments.

JSAF sensor modeling also needs to be expanded to include a chance of misidentifications. The confusion matrix methodology used by SLAMEM for this has become accepted by the combat modeling community and will be incorporated in the resulting model. The SLAMEM team is also working on a new model of target recognition that uses Bayesian networks to combine compositional evidence as to the identity of the target that may be applicable to this problem (Castleberg, Colon, and Berger 2006).

SCALABILITY

Since the previous ROE model would never engage an entity of the same or neutral force and the computation of visibility and target acquisition is an expensive process, the temptation to utilize the force attribute as a filtering criteria prior to the computation was irresistible. The justification for this approach is that there is no point in spending so much effort on determining whether you can identify an entity, if you already know that you will ignore it. This type of filtering was extended from the local target acquisition model to data distribution management (DDM) where entities were routed by force so that simulators could reduce their subscriptions to friendly and neutral entities. However, in the asymmetric environment one needs to evaluate information about the items that the agent is carrying and the behavior he is engaging in. The force based DDM scheme breaks down and we must look at every entity to determine which ones are hostile and should be targeted. So we have had to look at other ways to control computation. The first change we have made was to go to a distributed sensor model for JSAF visibility calculations. SLAMEM has used this approach since 1999 (McGarry and Torpey 1999). Since the civilian entities do not run sensor models and they make up the bulk of the simulation entities, distributing the visibility computation spreads it out over many more computers. We are also looking at other measures for increasing the efficiency of the model. For example, currently the model does not include a penalty for trying to process large numbers of targets. It is assumed that any number of targets can be processed in the same amount of time and many of the fields of view are artificially large since we don't have a good model of visual attention. We are looking at improving our model of visual search so that each agent doesn't cause as much remote entity state information to be processed. We also feel that it is very important to include the confusion effect of trying to find an individual in a crowd.

CONCLUSION

Asymmetric warfare against insurgent forces breaks some of the fundamental assumptions that combat simulation designers built upon. These assumptions include that the side combatants are fighting for will be easily identifiable and that combatants will not attack their allies or neutral parties on purpose. It is time to start evolving our modeling of target identification and ROE to better represent insurgent combat. We have started this process at the JFCOM Joint Futures Lab and have made some initial progress. We have gained insight into the many challenges involved including developing new sensor models for the detection of hand held objects and the recognition of suspicious or hostile behavior. These models are under currently under development at NVESD. Another challenge is how do deal with high population density environments without the ability to prefilter by force. We are addressing this problem via distributed sensor models. We hope that when fully implemented our solutions will enable a much wider range of computer experimentation.

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