Developing a Crowd Federate for Military Simulation

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Abstract: Crowds of non-combatants play a large and increasingly recognized role in modern military operations, and often create substantial difficulties for the combatant forces involved. U. S. military actions in Mogadishu, Bosnia, and Iraq exemplify the significant effects crowds may have on military operations. However, in spite of their potential significance, realistic models of crowds are essentially absent from current military simulations. For the scenarios considered likely in future conflicts the absence of crowds and of non-combatants in general would be a serious departure from realism.

We are engaged in a two-phase research project aimed at developing a crowd modeling capability for military simulation. The first phase, recently completed, consisted of three parts: a requirements analysis to identify military simulation crowd modeling requirements, a literature survey to examine psychological research relevant to crowd modeling, and a design study to explore design issues in the implementation of a crowd simulation. In the second phase, now well underway, we are developing a crowd simulation, implemented as a distributed simulation federate, that will be interoperable with existing military simulations and will have a credible psychological basis for the crowd behavior it generates.

In this paper we report on the crowd modeling project at an overview level. We first summarize the results of the first phase. Then the current status of the project is explained, including the process being employed to acquire direct information regarding the behavior of crowds, the design and implementation of the crowd federate, and the concept and development of historically accurate reference scenarios for use in validation and experimentation. Technical and modeling challenges (e.g., terrain correlation and quantitative psychological models) encountered so far will be identified and discussed. Finally, the future plans for the project are laid out, including two experiments planned to test the crowd federate; the first will examine the level of crowd behavior fidelity needed and the second will test the architectural reconfigurability of the crowd federate.

1. Introduction

This section discusses the motivation for the research, presents an overview of the project, and describes the structure of the paper.

1.1 Motivation

Crowds of non-combatants play a large and increasing role in modern military operations, and often create substantial difficulties for the forces involved.

> "In Somalia, U. S. Marines often faced hostile crowds of rock-throwing women and children. In Bosnia, U. S. Army soldiers had to disperse angry mobs of Serb hard-liners near the town of Banja Luka. More recently, Danish, French, and Italian forces attempted to control riots between ethnic Albanians and Serbs in Mitrovice, Albania." [1]

> "All military operations, large or small, have a crowd control/crowd confusion factor. … [C]rowds are one of the worst situations you can encounter. There is mass confusion; loss of control and communication with subordinates; potential for shooting innocent civilians, or being shot at by hostiles in the crowd; potential for an incident at the tactical level to influence operations and policy at the strategic level." [2]

In spite of the military challenges and risks imposed by crowds, models of crowds are essentially absent from current production military simulations. This omission has been understandable in the context of legacy simulations that were historically focused on large-scale engagements between heavy mechanized forces in primarily non-urban settings. However, in the last decade the threat has changed and future engagements are expected to often involve lighter forces in urban settings. In simulations of such scenarios the absence of crowds and of non-combatants in general is a more serious departure from realism. The absence of models of crowds in military simulation, and the need to include them, has been widely recognized.

> "Military forces are increasingly called upon to support operations other than war in which they come into contact with civilian populations. In some cases, the interaction takes place with crowds of civilians. Unfortunately, the computer generated forces that support virtual training systems do not yet support the simulation of crowds of civilians." [3]

> "Representations are needed for … (neutrals or civilians) to represent operations other than war and the interactions among these forces." [4].

> "[T]he ability to represent the behavior of crowds is currently lacking in military modeling and simulation …" [5]

> "With the Army's growing emphasis on low-intensity conflicts and operations other than war, the need to consider the civilians that live in the environment in which our forces will operate has become increasingly important. … [C]ivilian populations can have a profound effect in a crowded battle space. … There is, however, little representation of the civilians in today's military simulations." [6]

This research described here is intended to develop crowd models for use in military simulation.

1.2 Project overview

VMASC is engaged in a two-phase research project aimed at developing a crowd modeling capability for military simulation. The first phase, now complete, consisted of three parts: a requirements analysis to identify military simulation crowd modeling requirements, a literature survey to examine psychological research relevant to crowd modeling, and a design study to explore design issues in the implementation of a crowd simulation [7] [8].

In the second phase, now well underway, we are developing a crowd simulation, implemented as a distributed simulation federate, that will be interoperable with existing military simulations and will have a credible psychological basis for the crowd behavior it generates. The second phase of the project has seven interrelated tasks. They are:

1. *Crowd federate implementation*; design and development of a simulation that generates and controls crowd members, is interoperable with existing military simulations via HLA, and has a reconfigurable architecture to allow later replacement of its component models.
2. *Cognitive model development*; acquisition of psychological information describing the behavior of crowds via both literature review and direct psychological research, the development of a computational model of crowd member behavior based on the psychological information, and the integration of that model into the crowd federate.
3. *Requirements analysis continuation*; continuation of the process of identifying requirements for crowd modeling in military simulation.
4. *Historical survey*; study and analysis of historical incidents where crowds had a significant effect on the course or outcome of military engagements.
5. *Reference scenarios*; development of documented, historically accurate scenarios in a military simulation of historical events involving crowds, for testing and validation of the crowd federate.
6. *Experiments*; conduct of two experiments planned to test the crowd federate, the first to examine the level of crowd behavior fidelity needed, and the second to test the architectural reconfigurability of the crowd federate.
7. *PMFserv evaluation*; independent evaluation of a psychological model based on performance moderator functions.

The relationships between the three tasks of Phase 1 and the seven tasks of Phase 2 are summarized in Figure 1.

1.3 Structure of this paper

This paper has five main sections. The next section summarizes the completed first phase of work, which was a review of requirements and existing capabilities for crowd modeling. Following that, separate sections describe four of the project tasks: crowd federate implementation, cognitive model development, reference scenarios, and experiments.

2. Phase 1 summary

During the completed first phase we performed necessary preparatory work prerequisite to the successful implementation of a useful crowd simulation capability. That phase had three tasks:

1. Identify and analyze requirements for crowd modeling in military simulation.
2. Examine existing psychological research and models relevant to crowd modeling.
3. Develop an understanding of design considerations for a crowd simulation.

This section summarizes those tasks; complete details are also available [7] [8].

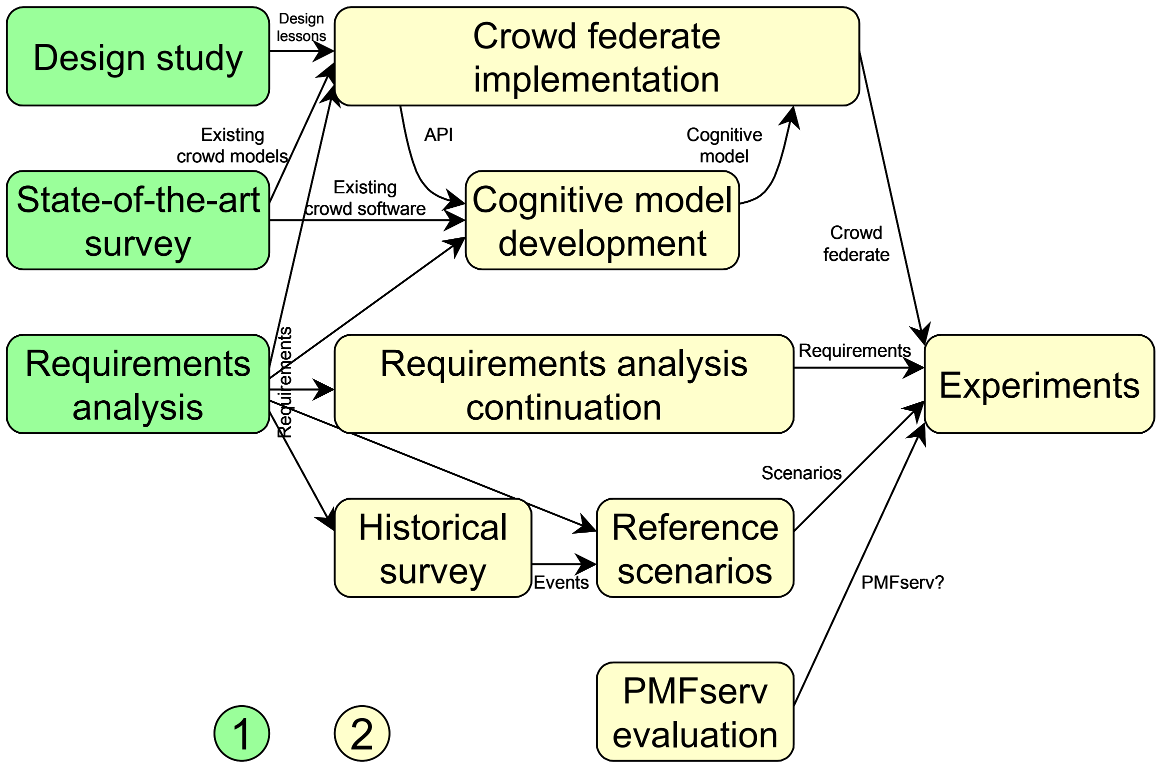

Figure 1. Task structure of the crowd modeling project.

2.1 Requirements analysis

VMASC consulted with M&S users in the joint community (and others) regarding their current and anticipated needs for crowd modeling in military simulations and surveyed published sources calling for crowd modeling. We used an adaptation of a methodology previously proposed for analyzing requirements in the domain of human behavior modeling [9]. That method asserts that the intended purposes of a simulation should determine its fidelity requirements.

We added an initial step to the method wherein the simulation purpose was determined from application area[1] and warfare level[2]. A combination of application area and warfare level constitutes a use category; each use category specifies a class of simulation purposes. From those purposes entity types, cognitive tasks, and fidelity can be determined. However, in our analysis, attention is restricted to crowd entities.

1. Use category (application area and warfare level) → Purpose
2. Purpose → Entity types required (crowd entities assumed)
3. Purpose and entity type (crowd entities assumed) → Cognitive tasks (behaviors) required
4. Purpose and Cognitive task (behavior) → Fidelity required

Following the revised method, crowd modeling requirements were analyzed in each of twelve use categories, the possible combinations of the four application areas and the three levels of warfare. The analysis was done by interviewing military simulation experts, focusing on simulation users rather than developers, and surveying military simulation literature for assertions regarding crowd modeling requirements.

There was a good consensus that crowds were needed in military simulation. However, there was less agreement on what the specific requirements were, and even less on how the requirements were expressed. The requirements, both as given by the users and drawn from published sources, were stated in several different ways: needed crowd behaviors, e.g., "take hostile action against combatants"; military mission types for which crowds were generally needed, e.g., "urban warfare"; and effects that a crowd might have on a scenario that needed to be

[1] These application areas were used: training, analysis, experimentation, and acquisition.
[2] These levels of warfare were used: tactical, operational, and strategic.

modeled, e.g., "road congestion". Because of the wide variety of crowd modeling requirements identified, it seems clear that a single crowd behavior model is unlikely to satisfy all of the requirements. The largest number of requirements were found at the tactical warfare level and for the training application area.

2.2 Survey

A survey of the current state-of-the-art in crowd modeling was conducted from two perspectives. The first perspective was psychological; here we surveyed the psychological research literature for research relevant to understanding and modeling the behavior of crowds. Special attention was given to research that considered crowd behavior in military scenarios, but other scenarios, including civil unrest and sporting event riots were also considered. Over 50 references for both descriptive (qualitative) and predictive (quantitative) models associated with crowd modeling were studied. The literature surveyed drew largely from the cognitive psychology, social psychology, sport psychology, sociology, police, and military literature. Research of primary interest was non-combatant crowd behavior during military operations. The secondary literature, which was much more plentiful, was focused on riots and sport fan behavior.

The second perspective was engineering; here we identified models and simulations with capabilities relevant to crowd modeling that have been or are being implemented as computer systems. Both models of crowd cognitive behavior and crowd physical behavior were of interest. VMASC assessed the capabilities of those systems.

The psychological literature had many sources that describe and categorize crowd behavior in a qualitative way. Four main crowd types have been identified, with differing behavioral tendencies: aggressive, escapist, acquisitive, and expressive [10]. A crowd can exist for any combination of these reasons or change its type due to the unfolding situation [11]. During the time they exist, crowds seem to pass through three specific stages of behavior: assembling, gathering (perhaps "acting" would be more descriptive), and dispersal [12]. The assembly stage consists of the process and motivation behind the initial collection of people. During the gathering stage a crowd begins to engage in collective behaviors. These behaviors can range from peaceful actions such as singing or cheering to violent behaviors and the use of weapons. Eventually the crowd will discontinue its collective behaviors and disperse; the dispersal process may be either forced or routine. A large number of situational, cultural, and personal factors have been identified and documented in the literature as affecting crowd behavior in each stage.

2.3 Design study

To learn about significant challenges and potential solutions in the implementation of a simulation of crowd behavior, we conducted a design study of such a simulation. The design study included consideration of details of the crowd simulation's input and output, software architecture, essential algorithms, and data assumptions. It began with certain premises:

1. The crowd federate would be implemented as an HLA federate.
2. Other federates in the federation would be responsible for the non-crowd entities.
3. The crowd entities would be individual human characters, rather than aggregations.
4. The behavior of the crowd entities would be controlled by behavior models, rather than by a human operator.
5. The federate could be used in a virtual simulation environment, so both the behavior and the visual appearance of the crowd entities were of interest.

VMASC researchers reviewed existing software and simulations with capabilities related to crowd modeling. Versions of some of this software were acquired and installed at the VMASC laboratory. An investigative software development process was used to create an exploratory prototype for a crowd federate. We designed multiple crowd federate architectures and a series of increasingly sophisticated versions of the prototype were built to refine the architecture concepts. Using the exploratory prototypes, six implementation experiments were conducted to learn about potential problems and solutions in implementing a crowd federate. In addition to testing architectures, the experiments included establishing interoperability with a combat simulation (JSAF), determining the utility and usability of crowd member physical behaviors available in commercial software packages, and working out a process of developing terrain databases for the crowd federate that would be correlated with those used by the combat simulation. (Terrain development for the crowd federate is explained in more detail in a companion paper [13].)

Figures 2 and 3 are images of crowds generated by the prototype crowd federate during the design study. The terrain in the figures is a digitized version of the Quantico urban combat training facility.

Figure 2. Crowd with random movement.

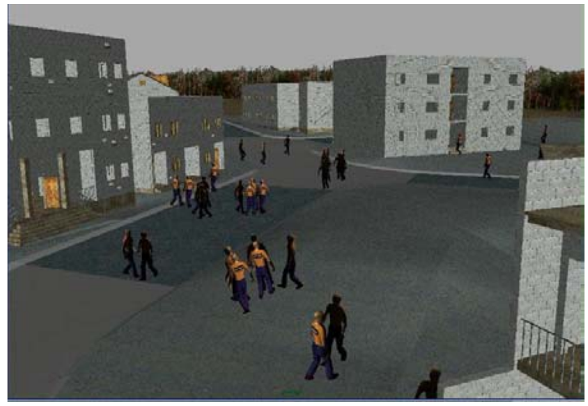

Figure 3. Crowd with flocking and path following.

2.4 Phase 1 findings

The findings of the first phase included two that provided important focus to the second phase development. First, we found that the greatest requirements for a crowd simulation capability were in real-time tactical training applications. Therefore, the crowd federate is intended to be used for that application. Second, we realized that there is an important distinction between crowds (hundreds to thousands of people) and populations (tens of thousand to millions of people) in terms of size, behaviors, duration, extent, and effects on military operations. In the second phase we are concerned with simulation crowds, not populations.

3. Crowd federate implementation

This section describes the ongoing crowd federate implementation, focusing on the architecture of the crowd federate and the capabilities of the current prototype.

3.1 Crowd federate architecture

A central task of the ongoing project is to design, implement, and test a crowd federate, i.e., an HLA-compliant simulation that models crowd behavior in the context of a real-time, individual combatant-level simulation federation. The crowd federate will have a multi-layered reconfigurable software architecture, shown at a high level in Figure 4. The architecture separates the model(s) for physical behaviors (e.g., walking, running, route following, stone throwing) from the model(s) for cognitive behavior (e.g., decision making). The cognitive model selects the behaviors a crowd member will perform whereas the physical model carries out those behaviors.

The crowd behavior applications programming interface (API) provides the interface between the cognitive and physical models and is central to the federate architecture. The API allows the integration of separately developed cognitive and physical models. The API is intended to operate in both directions. It facilitates control of the physical model by the cognitive model by providing a repertoire of physical behaviors and drives the cognitive model by relaying physical sensory, event, and state feedback from the physical model to the cognitive model. (The API and the design process that led to it are documented in a companion paper [14].)

We intend for the architecture to provide a reusable infrastructure within which other crowd models (cognitive or physical) developed by other researchers can be tested. Ideally, separating the cognitive and physical models from each other and linking them with a carefully design API will make it possible to modify or replace models of one type without affecting those other.

3.2 Crowd federation

The crowd federate will be both tested and later used for experiments within the context of an HLA federation. As currently envisioned, it will consist of five federates:

1. *Crowd federate.* The crowd federate will simulate the crowd members in the test and experimental scenarios.
2. *SAF federate.* A SAF (Semi-Automated Forces) federate will simulate the combatants and combat actions in the test and experimental scenarios. We currently are using JSAF; there is a possibility we will also use JCATS.
3. *Control federate.* The control federate will control and monitor the federation execution.
4. *Data federate.* The data federate will collect and analyze data during the federation execution and provides playback for post-execution analysis.
5. *Viewer federate.* The viewer federate will provide a three-dimensional view into the federation execution to observe events during test and experimentation.

We plan to use commercial products for the control, data, and viewer federates.

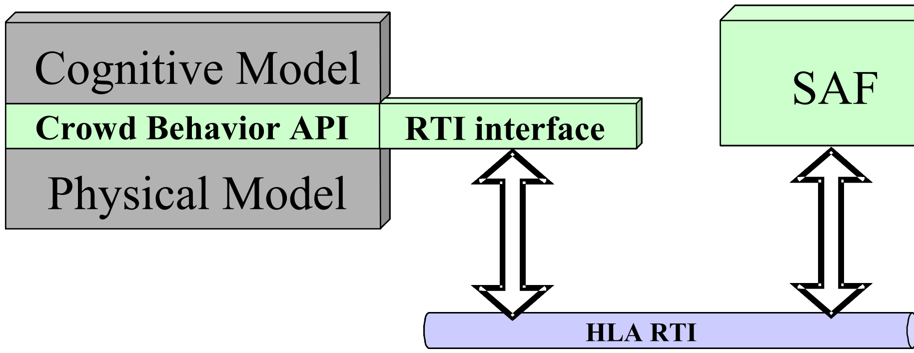

Figure 4. Crowd federate top level architecture.

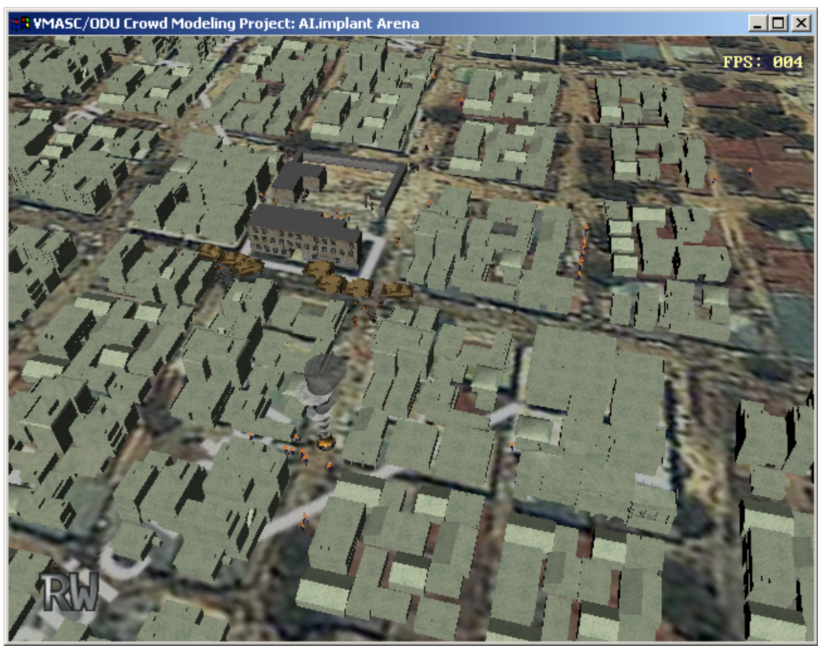

Figure 5. Crowd federate test with the Mogadishu scenario.

3.3 Crowd federate prototype

Development of the crowd federate software is ongoing. The current version of prototype crowd federate has working versions of the API, physical model, and RTI Interface modules. Figure 5 is an image from a test of the crowd federate; it shows a moment from the Mogadishu reference scenario (the reference scenarios will be discussed later). In the figure, the crowd members are controlled by the crowd federate, while the combatant soldiers and vehicles are controlled by JSAF. The cognitive model module in the current prototype is a temporary version based on simple decision tree logic and has no psychological basis. It serves to test and demonstrate the prototype while the objective cognitive model is developed.

4. Cognitive model development

The development of the crowd member cognitive model to be integrated into the crowd federate is the topic of this section. First, the psychological studies being conducted to acquire direct information regarding the behavior of crowds are described. Then the current status of the cognitive model is reported.

4.1 Psychological studies

The goal of the ongoing psychological studies is to gather information for a psychologically-based cognitive model in the crowd federate. Thus far, the project has taken a three-pronged approach to these studies: (1) naturalistic observation, (2) interviewing subject matter experts, and (3) survey research.

Naturalistic observation. The Seattle Police Department supplied five hours of raw video footage of protests at the World Trade Organization (WTO) meeting from the November 29 through the December 3 1999. The goal of the demonstrators was to disrupt the WTO meeting. To analyze the crowd behavior exhibited at this event, six graduate and undergraduate students participated as subjects in a naturalistic observation study. Subjects coded the frequency of occurrence of 55 behaviors in increments of ten minutes. Two subjects went back and rated the level of aggression in increments of ten minutes. Descriptive statistics were used to analyze the data. Means and percentages were calculated to determine which behaviors occurred most frequently. Reliability measures were also calculated. Some of the most frequently occurring behaviors include standing on elevated structures, yelling and shouting, raising flags, filming by media, and chanting. Aggressive behaviors rarely occurred but were highly effective in disrupting the event when they did occur. These include throwing glass bottles, fighting, jumping on moving vehicles, looting, and blocking the road by groups lying down across the street. Overall the subjects' observations of the behaviors were reliable. Reliability increased during the course of the five hours of observations. Standard deviations were also examined as evidence of reliability. Higher deviations occurred for the more frequently occurring behaviors. Future research will utilize a similar technique but with more subjects and each coding fewer behaviors. Further research will examine other demonstrations particularly other WTO protest.

In a separate naturalistic observation study, crowd member and control force behaviors were observed at Fort Polk's MOUT training facility representing three Iraqi villages. The exercise included various training scenarios involving the military and contracted crowd members, police and guard units. Crowd events occurred during negotiations between soldiers and town leaders, search for weapons, protesting arrests, over food and electricity shortages and during a funeral procession involving a terrorist attack. Crowd behaviors included the formation of two crowds, one male and one female, voicing protest through chanting and heckling, looting, curiosity on arrival of troops and rushing humvees, assembly, and dispersal. Flashpoints observed include arrival of troops, gunshots and explosions, arrest, not recognizing the village Chief upon arrival, terrorist attacks, and late payroll. Cultural factors resulting from the observations include the curious nature of the Iraqi people, strength of the need for revenge, strength of humiliation effect, and importance of addressing individuals with direct eye contact and without sunglasses. Lessons learned from these observations were that training lacked cultural awareness and consideration of cognitive psychological factors.

Subject matter expert interviews. Both structured and unstructured interview techniques are being employed with senior level Non-lethal Weapons Trainers and Police officers with extensive crowd experiences. These interviews are designed to better understand the cognitive processes and relevant issues associated with crowd member and control force interactions. For instance, do crowds perceive non-lethal weapons as a threat? Some of the challenges that have been uncovered include cultural sensitivity, difficulty of negotiations to lack of interpreters, distinguishing gunmen, organized and paramilitary tactics, denying the area, what to do with the crowd afterwards, arresting the leader and the generality of current research. Typical flashpoints include lethal weapons pointed at a soldier and the use of irritant chemicals. Some of the best ways to avoid a crowd riot include the presence of interpreters, a means for communicating with the crowd and the presence of civil affairs people.

Survey research. A survey was developed and field-tested on six soldiers on active duty in Iraq. The survey examines various psychological variables and their relation to crowd violence. The survey includes both open-ended items and Likert scale items. Open-ended items get at the types of crowd events, demographics of the crowd, the interaction with the crowd, temperament of crowd, events leading up to the crowd event, purpose of gathering, and presence of weapons. The survey also asks questions regarding best practices and attempts to understand what was most effective in dealing with the crowd and re-establishing peace. A number of items question the soldiers' level of experience with crowds. Finally the survey examines a number of crowd factors from the literature and the aforementioned WTO study. Respondents are asked to rate each factor on a 5-point Likert type scale representing the strength of the relation to the crowd event turning violent. Some sample factors from preliminary analysis that were rated as highly related include presence of instigators within crowd, presence of weapons within crowd, willingness to take risk, peacekeeper aggression, size of crowd, use of alcohol and drugs by crowd, societal acceptance of violence, commitment to cause and presence of organized crowd leadership. Future versions of this survey will be administered to a larger sample of troops who have now returned from a yearlong deployment in Iraq as well as troops currently deployed to Iraq, Bosnia, and Afghanistan. In addition to identifying the strength of the relationships of variables to crowd incidents, we plan to develop factual case studies of soldiers encountering crowd situations in Iraq. This would encompass the following situations: planned political protests; spontaneous crowds that form following an incident, such as the forced-landing of a disabled helicopter; food and other-civilian issue related riots; non-hostile crowds that may pose a potential but yet unrealized threat; hostile crowds that use other civilians (e.g., children) as human shields.

4.2 Cognitive model status

Development of the cognitive model is just beginning. As mentioned earlier, the current prototype crowd federate has a temporary cognitive model with no psychological basis. As the psychological studies just described start to produce information upon which a computational model could be based, we have begun considering alternative modeling paradigms for implementing the cognitive model (e.g., [15]). However, this is still an open question in the project.

5. Reference scenarios

A reference scenario is a highly detailed scenario based on a historical event, with great care taken to reproduce the event as precisely as possible. Included in a reference scenario are: terrain; military force personnel; military force equipment; military mission and rules of engagement; military orders; crowd size and composition; and crowd behavior repertoire. These details, once documented, are implemented as a scenario in the combat simulation to be used in the Crowd Federation (currently JSAF). In our current work we are developing two reference scenarios. The first consists of two vignettes from the Battle of the Black Sea, Mogadishu Somalia, in 1993.

In 1993 the United States deployed troops, known as Task Force Ranger, on a peacekeeping mission to Mogadishu, Somalia on the eastern coast of Africa. On the afternoon of October 3 1993 over 100 soldiers from Task Force Ranger, supported by nineteen aircraft, departed the Task Force Ranger compound on a routine mission to capture two chief lieutenants of Mohamed Farrah Aidid, leader of one of the principal warring factions in Mogadishu. Intelligence placed these men in a building near Bakara Market in Mogadishu, an Aidid stronghold. The plan was to insert Special Forces by helicopter to secure the building. Concurrently, four "chalks", about twelve soldiers, of U. S. Army Rangers would fast-rope from Blackhawk helicopters to defend the perimeter of the target building compound. A ground convoy of twelve Humvees and trucks would then evacuate the troops and prisoners. The mission was planned to take less than one hour. In the insuing action two Blackhawk helicopters were shot down and a portion of the force was pinned down overnight until rescued the following day. The mission resulted in the capture of two high-ranking Aidid supporters, eighteen U.S. dead and estimates of hundreds, perhaps thousands, of Somali casualties. This event is the subject of the well-known book and motion picture *Black Hawk Down* [16].

The Mogadishu scenario was selected as the subject of a reference scenario based upon two significant factors.

1. *Well documented event*. For a reference scenario to effectively represent a historical event that is the subject of simulation it must be well-documented, meaning a wealth of reference sources must be available. References should be primary sources when possible. For example, the partial sequence of events found in Rysewyk [17] is a primary source. Bowden in his book *Black Hawk Down* states the Mogadishu event "may well be the the most thoroughly documented incident in American military history" [16].
2. *Desired level of crowd interaction*. In the Mogadishu action, the crowd consisted of militia elements and civilian participants, exhibiting behaviors varying from fleeing to obstructing the progress of military forces to combat engagement of military forces. The crowd interaction resulted in a measurable effect on event outcome, specifically length of operation, military force and crowd casualties, and degrees of mission accomplishment.

Elements of a reference scenario include data concerning terrain; military force personnel; military force equipment; military mission and rules of engagement; military orders; crowd size and composition; and crowd behavior repertoire. These elements are captured in the referenced execution matrix, referenced sequence of events, and terrain database. The execution matrix details the military mission by breaking out military force personnel and equipment and orders in a matrix format. Each entry is referenced to a source document. The execution matrix represents the intentions of the military force. The sequence of events details the actual events of the historical action and includes crowd as well as military force events. Like the execution matrix, each entry is referenced to a source document. The terrain database includes imagery, topography, and structure information.

Validation is accomplished by entering the scenario into the combat simulation with and without crowd interaction. Experiments are conducted using varying degrees of crowd interaction. The hypothesis is that the simulation results with crowd interaction will be closer to the historical events in the reference scenario than the simulation results without crowd interaction. While it is not expected that the simulation could ever reach the exact outcome of the historical event, similar types of effects can be noted. Another interesting event can be considered in the "null interaction" in which the crowd has no effect on event outcome.

Crowd Behavior Fidelity Level	Experimental Configuration	Crowd Behavior Description
None	SAF only, no Crowd federate	Crowd members absent
Very low	SAF + Crowd federate	Crown members motionless "statues"
Low	SAF + Crowd federate	Crowd members move randomly
Medium-low (?)	SAF + Crowd federate	Crowd members with limited behavior
Medium-high (?)	SAF + Crowd federate	Crowd members with full behavior
High (?)	SAF + Crowd federate + operator GUI	Crowd members with human-controlled behavior

Figure 6. Possible levels of fidelity in the crowd behavior fidelity experiment.

Additional reference scenarios will provide more opportunity to test, validate, and demonstrate the Crowd Federate developed in this project. In later phases of this research additional reference scenarios will be considered, including the 1982 Jakarta Tanjung Priok event, actions in Bosnia in 1997, the 1999 Seattle World Trade Organization protest, and the 2003 Iraqi Freedom Mosul operation.

6. Crowd simulation experiments

The implemented crowd federate and federation will be used to conduct two experiments in crowd simulation. The first experiment will investigate the level of crowd behavior fidelity needed to significantly affect the outcome and utility of the simulation. Though the need for crowd modeling in military simulation has been recognized, it is not clear how much fidelity the models must have to be effective. This experiment will investigate the issue of "how much is enough" in crowd modeling fidelity; it will attempt to quantify expected effectiveness of the simulation as a function of the level of fidelity of the crowd behavior representation. There will be two independent variables in the experiment:

1. *Crowd behavior fidelity.* Multiple levels of fidelity of crowd behavior will be implemented in the crowd federate. Figure 6 shows a possible sequence of levels of fidelity.
2. *Military scenario type.* At least two distinct types of military scenario will be used. The reference scenarios previously described will be used as experimental scenarios.

The second experiment will assess the reconfigurability of the crowd federate's software architecture. It is an important objective of the proposed project to provide a reconfigurable software architecture for the crowd federate that can provide a context for other investigators to test and develop crowd behavior cognitive and physical models. To assess our success at achieving that objective and to provide guidance for improvements to the architecture, we propose to experimentally perform the integration of different cognitive models with different physical models using the architecture. For each experimental integration, the cognitive and physical models selected will be implemented or adapted as components within the crowd federate architecture and integrated into a working federate. The crowd federate will be tested using experimental scenarios designed to exercise the federate's capabilities. The difficulty of the component implementations, as well as the capabilities and fidelity of the resulting federate, will be assessed and analyzed.

7. Summary

VMASC is developing a crowd modeling capability for military simulation. The first phase of the project consisted of a requirements analysis to identify military simulation crowd modeling requirements, a literature survey to examine psychological research relevant to crowd modeling, and a design study to explore design issues in the implementation of a crowd simulation. The second phase, currently ongoing, is centered on the development of a crowd simulation implemented as a distributed simulation federate. The crowd federate will be interoperable with existing military simulations, will have a reconfigurable architecture, and will have a credible psychological basis for the crowd behavior it generates.

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