AUTOMATED SCENARIO GENERATION SYSTEM IN A SIMULATION

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ABSTRACT

Developing training scenarios that induce a trainee to utilize specific skills is one of the facets of simulation-based training that requires significant effort. Simulation-based training systems have become more complex in recent years. Because of this added complexity, the amount of effort required to create and maintain training scenarios has increased. This paper describes an investigation into automating the scenario generation process. The Automated Scenario Generation System (ASGS) generates the environment for the expected action flow in chronological order from several events and tasks, with estimated time for the entire training mission. When the user defines the training objectives and conditions, the ASGS automatically generates a scenario that includes not only the initial situation but also the sequential environmental conditions that will present the trainee with subsequent situations relevant to the training objectives throughout the entire simulation exercise. The latter is the main contribution of the research, as the flow of the training exercise can take many directions after start, based on the decisions made by the trainees. The system considers the current situation, and strives to present the trainees with subsequent situations that are consistent with the training objectives, yet in a manner that is natural. It takes advantage of contextualization to accomplish this. This scenario includes a degree of randomization to ensure no two equivalent scenarios are identical. This makes it possible to train different groups of trainees sequentially, who may have the same level or training objectives, without using a single scenario repeatedly. The SVS™ Desktop system is used as the development infrastructure for the ASGS prototype training system. The paper describes and discusses the ASGS prototype, the tests to which the prototype was subjected, the results obtained and conclusions reached.

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Simulation-based training, as is currently used by the US DoD, relies on very specific training objectives for a simulation session to achieve the overall objective of a highly trained warfighter. These training sessions, in turn, place the trainees in situations that will cause them to use the knowledge or skills being taught, reinforced or evaluated. These scenarios have been traditionally built by hand, through significant effort on the part of the instructor and/or the school staff. One goal of the Defense Advanced Research Projects Agency (DARPA) is to automatically generate new training initial scenarios (DARPA, 2006). Another effect of this is that when training several units with the same training objectives during one compressed time period of time (say over a week or two), only one scenario is typically built for all the units to be trained. Normal after-hours interaction with trainees that train earlier can cause those that train later to know what to expect when subjected to that scenario. This reduces the effectiveness of the training session. Our work described here automates the scenario generation process to greatly reduce the burden on the scenario developer. This system, by extension, permits the generation of equal but different scenarios to use on different units during a large training exercise. We have developed a prototype and have tested it extensively. This paper describes our approach as well as our results.

BACKGROUND

A *scenario* can be defined as "An outline or model of an expected or supposed sequence of events" (The American Heritage Dictionary, 2000). NATO Research and Technology Organization (RTO) states that a *scenario* "portrays a possible future situation in which military units and civilian resources are or might be employed." (NATO, 2005) The National Research Institute for Earth Science and Disaster Prevention (NIED) defines scenario as "the action pattern of routine work and completing short term goals at disaster outbreak" (NIED, 2005). A *situation* can be defined as that which "includes all the circumstances and things that are happening at a particular time and in a particular place." (The American Heritage Dictionary, 2000) In a military context, a scenario takes into consideration various factors, such as enemy forces, friendly forces, training objectives, configurations, situations including terrain, interactions, and constraints of executable events, among many other factors. In scenario generation, we define the blue forces (BF) to be the units of forces friendly to the trainee force (TF), while the red force (RF) is the enemy force.

Scenarios support detailed evaluations of future operating situations and force-structure solutions. Solutions of force structure to best fit a scenario are measured by the speed of readiness to the situations in the scenario. The readiness of a military unit in future operating situations is linked to the training of its members. Simulations are used for quantitative analysis by replaying a scenario in a long-term planning and evaluating the results (NATO, 2005).

Scenarios are prepared with models of entities, interactions, constraints, relationships and historical context. In this paper, we specifically define these terms as follows:

- ***Situation:*** the present state of affairs that includes all the things (e.g., the mission, enemy strength and location, weather condition, friendly assets, etc.) that are happening at a particular time and in a particular place.

- ***Scenario:*** models of situation immediately after the start of the simulation as well as throughout the simulation run. Scenarios should be designed to provide the trainee with the appropriate stimulation to perform the actions or employ the skills being taught. This should not only be in the initial conditions of the simulation but also throughout the entire run.

Initial Scenario

The *initial scenario* is the situation faced by the trainee or trainee unit at the outset of the simulation run. That is, the initial conditions. The initial scenario includes the mission, enemy forces, weather, terrain, allied forces, as well as any other elements relevant to the successful completion of the mission.

Subsequent dynamic scenario

While the initial scenario defines the situation at the start of the simulation, what happens thereafter is equally important in providing the trainee with the appropriate subsequent situations that will support the stated training objectives in the context of the mission. Scenarios, therefore, must reflect the current events during the entire simulation run and provide feedback after the simulation runs (Cloud and Rainey, 1998). Davis (2005) suggests that this is the next challenge in military modeling and simulation. This can be defined as the *subsequent dynamic scenarios*. The dynamic scenario can ensure efficient training throughout the entire simulation. Designing a system that automatically causes appropriate subsequent dynamic scenarios to be presented to the trainees is by far the most difficult part of the scenario generation process, whether it is done manually or automatically. We adapt Davis's suggestion of using context for military training.

SPECIFIC PROBLEM ADDRESSED

There are many reasons for the importance of automatic scenario generation. However, the following factors can be the most significant:

1) More specialized training scenarios are required for efficient training in complex tasks. However, because of the difficulties in generating a specified scenario, the scenario does not always produce good results for the trainees. Because development of a scenario is very complicated and time consuming work, or the scenario developer may not have enough knowledge about specific situations, the scenario developer sometimes finds it hard to consider all possible scene options.
2) The combat scene is diversified. It is not always easy for unskilled trainers to determine what should be included in the scenarios for effective training. There are some applications that provide support in generating a scenario by the scenario developer, but they merely manage information in large quantities, not control for generating scenarios.
3) The scenario does not typically consider the behavior representation of the computer-generated forces (CGFs). In our case, the RF and BF are computer-generated. Therefore, the RF's behavior in the scenario is always the same, regardless of how the trainee acts.
4) It can be difficult in scenario generation to represent a variety of forces.
5) It is difficult to develop several distinctly different but equivalent scenarios to present to various sets of trainees in a short period of time. Otherwise, trainees who have completed the exercise early share details of the scenario with other trainees who have yet to perform the same exercise, thereby reducing the effectiveness of the training for the subsequent units.

When the above problems are solved, the scenario generation process will be more efficient, effective and consistent for both the trainers and the trainees. No one to date has succeeded in building a completely automated scenario generator by merely entering the training objectives and mission description. This research addresses exactly this need.

OUR APPROACH TO AUTOMATICALLY GENERATING A SCENARIO

This section describes the general approach for developing a method capable of automatically generating a training scenario of arbitrary complexity. The resulting scenarios include both the initial scenario, as well as the dynamic subsequent scenarios.

General Description of the Process

Our system conceptually works in the following fashion. Initially, an instructor inputs training conditions via a user interface. The instructor selects a training objective and mission objectives from a menu list provided by the system. Training objectives are described as short phrases, such as "learning how to march on a position" and "learning how to defend a position against the enemy". Mission objectives can also be described with phrases such as "road march to a position" and "secure a building". Then, the instructor selects a level for the training exercise, such as *novice*, *intermediate*, *advanced* or *expert*. Next, the instructor selects the scenario generation mode as *automatic* or *manual*. Depending on the choice of training level, some conditions can be determined automatically, such as the number of friendly and enemy forces (*few*, *some*, *many*), the enemy strength (*weak*, *strong*, *armored*, *intelligent*), enemy location (*wide open*, dug in, *concealed*) and tactics of the enemy (*disorganized*, *aggressive*, *surprised*, *hit-and-run*). Then, environmental conditions are specified by the instructor, such as terrain (*paved road*, *dirt*, *vegetation*, *desert*, *jungle*, *mountain*, etc.), environment (*shielding*, such as a building or a rock) and weather conditions (*day* or *night*, *rain*, *snow*, *fog*, *cold*, *hot*, *mild*, etc.), and other factors. Because they are heavily dependent on the training objectives, these factors are better chosen by the instructor. However, the system can provide preset environmental conditions if requested. For example, specifying a Middle East winter set, the system can offer as the terrain a mountainous region, the weather condition as dry, cold and sunny, etc. The instructor will also have the option of overriding the automatic determination of the above parameters and inputting them manually and explicitly. Lastly, if the instructor wants to consider other factors such as additional constraints, time, and priorities of events or storyboards, these must be entered manually.

After the initial conditions are specified as indicated above, the system produces storyboards representing training derived from training objectives and/or mission objectives. Storyboards involve enemies with roles, positions and tactics within the trainee's contexts. These roles, positions and tactics are designed to elicit from the trainee the behaviors, actions or skills he/they is/are to learn. The location in a storyboard is selected around the critical resources. For example, when a mission is to attack an enemy, the location in a storyboard can be selected from *bridge near the forest* or *a building on the top of the hill* which are controlled by the enemy.

Next, the expected trainee's action flows are generated in chronological order as several contexts and their transitions, events and tasks for each storyboard, with an estimated time for the entire training mission. These set a trainee's conditions and standards that depend on the initial scenario configuration. It puts the training mission into motion, adding time and expected actions on the part of all actors.

Finally, the setting of data such as position of training field or contexts about situations is translated to an application format. The system also prepares for events to occur later. Figure 1 depicts this process graphically.

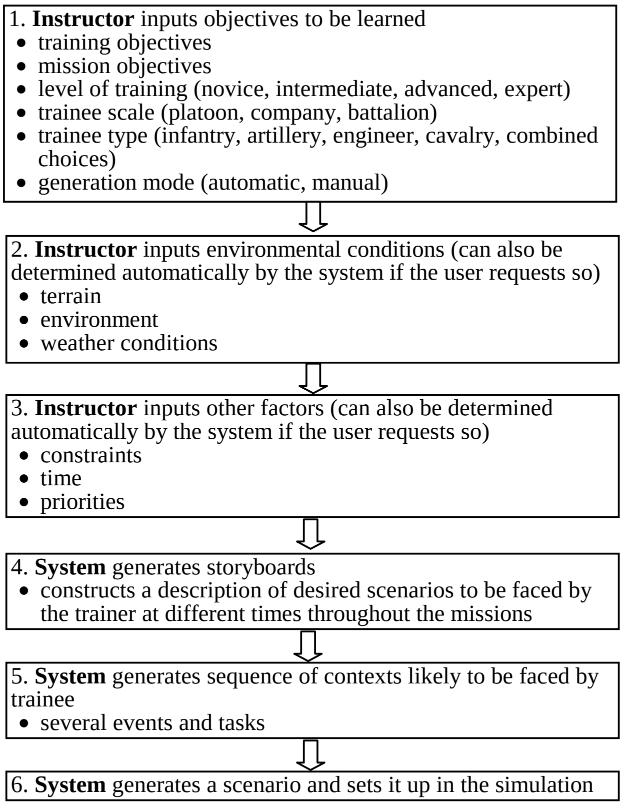

Figure 1 – Steps for Generating a Scenario

The Automated Scenario Generation System (ASGS)

The Automated Scenario Generation System (ASGS) generates a scenario event automatically for a military-based training system with some randomization to ensure that no two equivalent scenarios are identical. The ASGS makes equivalent, yet slightly differing training scenarios that can be easily built for different sets of trainees. This is important when several groups of trainees are evaluated at nearly the same time. The development of the ASGS is discussed in this section.

ASGS has several features:

1. Captures the training and mission objectives from the training author.
2. Enables customization of the initial conditions.
3. Divides terrain into several situations as storyboards which are automatically generated.
4. Sets action contexts of both the trainee forces and red forces to each storyboard.
5. Translates a data format to a training system that adapt SVS (the Synthetic Virtual System) desktop systems in the prototype ASGS.

The following Figure 2 describes the ASGS system's high-level algorithm. The left side represents the ASGS developed in this investigation and the right side represents the general training system.

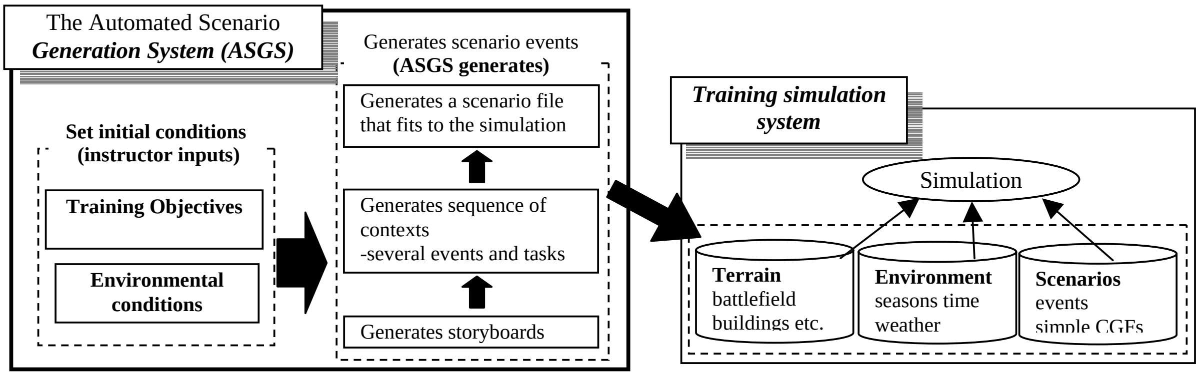

Figure 2 - ASGS System description

The ASGS generates the scenario and the workflow as described in the following Figure 3. There are two phases: 1) initial conditions are set and 2) scenario event is generated. The following discussion describes the steps in Figure 3 in greater detail:

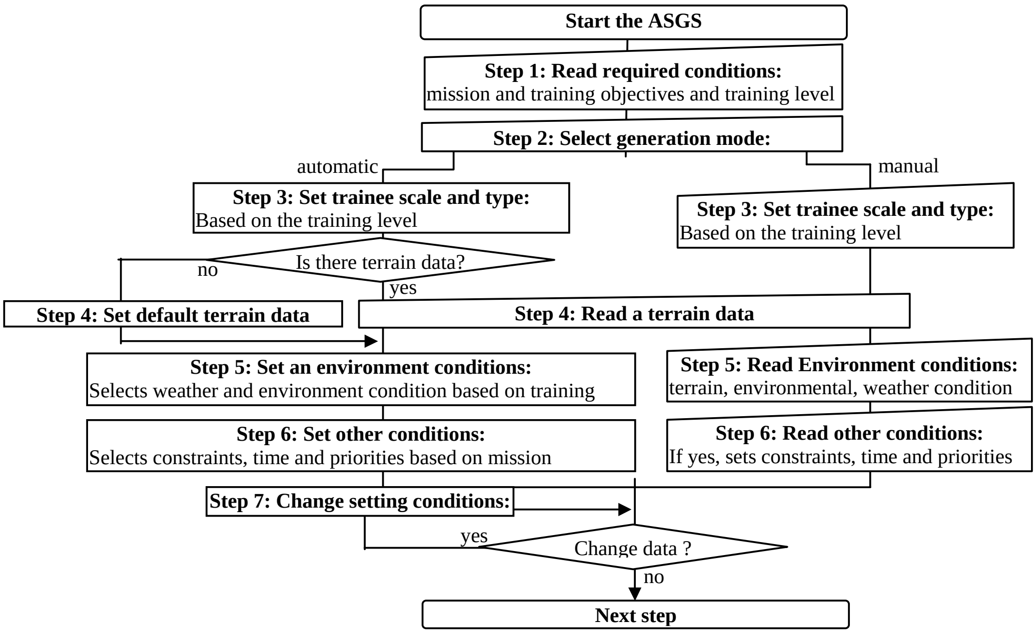

Figure 3 - Flow chart of setting initial conditions

Step 1) The instructor sets required training conditions via a user interface. Mission objectives and training objectives are supplied with pull-down menus by the ASGS. Both objectives include action, target and terrain data. For instance, the mission objective would be "occupy a building on a nearby hill" and the training objective would be "How to attack the building". Table 1 shows the many actions, target and terrains available. Both the mission and training objectives can select several goals.

Table 1: Actions, target and terrain

No.	Actions	Target	Terrain
1	Attack (surprise attack)	Military unit	Road
2	Attack (enemy prepared)	Bridge	Plains
3	Defense (expected)	Building	Hills
4	Defense (unexpected)		Forests
5	Reconnoiter		Deserts
6	March		Marsh
7	Patrol (routine)		Rivers
8	Guard (with precautions)		Lakes
9	Entry		Mountain
10	Occupy		City
11	Seek cover		

Step 2) After the instructor selects the mission and training objectives, ASGS provides the list of possible levels of difficulty to be selected for the training exercise. The instructor selects the level of difficulty from the list such as novice, intermediate, advanced or expert.

Step 3) The instructor selects the mode, *automatic scenario generation* or *manually specify a scenario*. Automatic mode does not mean fully automatic. The instructor can change the generated scenario as well in the automatic mode.

Step 4) When the instructor selects automatic mode, ASGS then internally selects conditions such as the number of friendly and the enemy forces, the enemy strength, enemy location and enemy tactics. Table 2 describes the possible values for these attributes. When the instructor selects manual mode, the instructor selects these conditions directly.

Table 2: The relation to the training level and the conditions in the automatic mode

Attributes	The training level			
	Novice	**Intermediate**	**Advanced**	**Expert**
# of BF	Many	Some	Few	Few
# of RF	Few	Some	Many	Many
RF strength	Weak	Armored	Armored	Intelligent
RF location	Wide open	Wide open	Concealed	Concealed
tactics of RF	Disorganized	Surprised	Aggressive	Hit-and -run

Step 5) ASGS reads basic terrain data or creates the basic terrain from the specification of the objectives. In this prototype, the system only reads the basic terrain data. This means that ASGS recognizes the terrain size and types. ASGS provides the environmental conditions such as weather and visibility, time of day, seasons and weather conditions (described in Table 3).

Step 6) The instructor can customize these factors and other conditions such as priority of events or storyboards, additional constraints and time.

Step 7) After setting initial conditions, ASGS displays the initial conditions selected and asks the instructor whether he wants to change any of the conditions. If yes, ASGS provides a selection of the conditions to change. When the instructor finishes selecting initial conditions, ASGS proceeds to generate a scenario, including storyboards.

Table 3: The weather, time and seasons

Attributes	The training level			
	Novice	**Intermediate**	**Advanced**	**Expert**
number of BF	Many	Some	Few	Few
number of RF	Few	Some	Many	Many
RF strength	Weak	Armored	Armored	Intelligent
RF location	Wide open	Wide open	Concealed	Concealed
RF tactics	Disorganized	Surprised	Aggressive	Hit-&-run

In the phase that generates scenario events, ASGS generates storyboards and the representation of the contexts that the forces are using contexts. Then, ASGS generates a scenario events file which is compatible with the training system. The following discussion describes the steps in Figure 4 in greater detail.

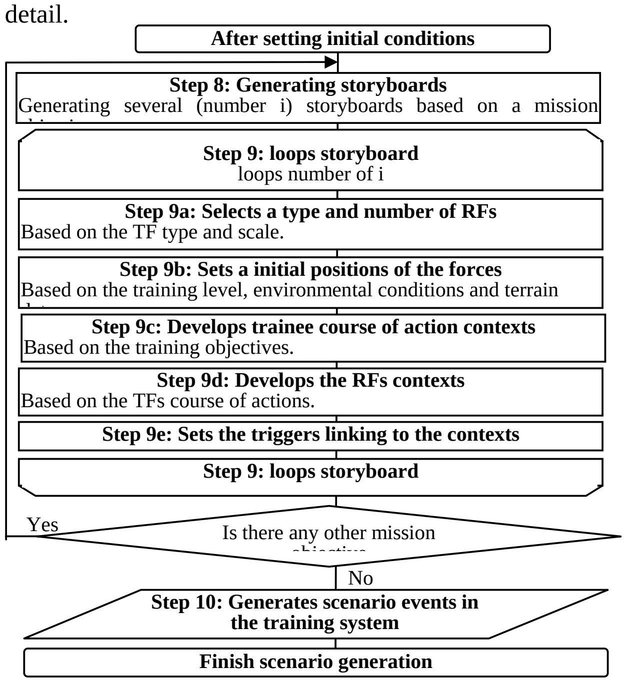

Figure 4: Flow chart of generating scenario events

Step 8) After setting the initial conditions, ASGS starts to generate a scenario. Step 8 generates storyboards. Storyboards need key terrain and critical resources. Therefore, ASGS automatically selects key terrain and critical resources. The instructor bases this on a mission objective that is input. For instance, when the mission is offensive operations against the expected enemy forces that occupy a building on a nearby hill, the key terrain is the hill and the critical resource is the building. If the instructor does not provide the terrain and critical resources, ASGS infers the terrain and the critical resource from the mission objective. If the instructor provides the terrain and critical resources, ASGS lists the terrain and the critical resource from the starting point to the goal of the mission. Moreover, the mission objective is restricted within this list. Then ASGS selects the area of the storyboards. The area usually defines two types: 1) approach the target area and 2) within the target area. In this mission example, the areas include "in front of the building" and "around the building". Each storyboard has its own local task. In this case, the story of the first storyboard starts from moving towards the building and finishes when reaching the building. Thus, the local task of the TF is to move towards the building. The second storyboard starts when attacking the RFs who occupy the building and finishes when beating the RFs. Therefore, the local task of the TF is to attack the RFs.

Step 9) After selecting key terrain, the critical resource and local tasks of storyboards, ASGS generates forces and their actions in each storyboard. ASGS generates the type and number of RFs based on the trainee level in a storyboard (Step 9a). Next, ASGS sets initial positions of TF, the BFs and the RFs in the storyboard (Step 9b). It is also based on the training level, environmental conditions and terrain data. Then, ASGS develops the expected course of action of the TFs in the storyboard (Step 9c). It is based on the training objectives and the local task which is created in step 8. For instance, when the training objective is assumed "How to attack the occupied building" and the local task of the first storyboard is "to move towards the building", the expected course of action of the TF is "approach the building with precaution". The local task of the second storyboard is assumed "to defeat the enemy in the building", the expected course of action of the TF is "to attack the RFs from concealed position".

After ASGS developed the TFs' course of actions, the RFs local tasks are determined (Step 9d). For instance, the task of the RFs in the first storyboard might be "patrol around the building". Another case can be "ambush the TFs". ASGS generates the course of actions of the RFs using contexts (Step 9e). Developing actions of the RF is described in detail in the following section. ASGS repeats to set the actions for all forces in each storyboard.

Step 10) After generating storyboards and contexts of the RFs, ASGS generates scenario events that consider the trainee tasks. ASGS generates the outputs for the training system as described in Tables 4 and 5.

Table 4: The outputs from the conditions

Condition	Setting data
Environment	Weather, start date and time
The storyboard	Number of storyboard

Table 5: The outputs with storyboard

The storyboard	Number
The trainee start location	(x,y) or (lat, lon)
The enemy type	Arms
The enemy location	(x,y) or (lat, lon)
The enemy tactics	Contexts (Set of behavior, plot route and time)
The trigger	Relation between the zone or the line and forces

General description of CxBR in ASGS

ASGS uses Context-based Reasoning (CxBR) and its context-driven approach to generate the behaviors of the Red and Blue forces in subsequent dynamic scenarios. The RF and the BF are in fact CGF's controlled through CxBR. The context of the RF causes a reaction on the part of the TFs, thereby forcing them to adopt a context related to what the trainees need to learn. Thus, the RF contexts depend on a TF's course of action. In ASGS, the BF obeys the TF. If the BFs individually make a decision, that influences the course of action of the TF. The instructor cannot judge equally in that scenario. Therefore, the BF needs a trigger from the TF for transitions to attack-context or defense-context. The hierarchy of the CxBR model is described as Figure 5.

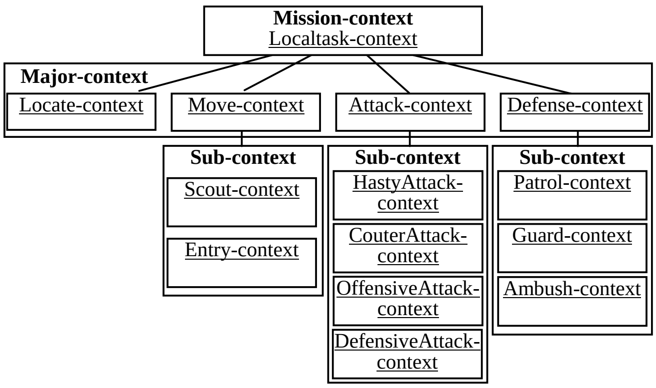

Figure 5: ASGS context hierarchy diagram

The following discussion describes the CxBR model in Figure 5 in detail:

Localtask-context as mission-context is the top-level context in ASGS. The context has four attributes: 1) mission objectives, 2) training objectives, 3) local task of each storyboard and 4) training level. These attributes are inherited by the subordinate contexts. The Mission-context has four major-contexts, which are the main control elements for agent behavior in

CxBR. The four major-contexts are Locate-context, Move-context, Attack-context and Defense-context. Some major-contexts have several sub-contexts in case it becomes necessary to display a more detailed behavior representation. Each major-context is described as follows:

1) **Locate-context** is used as the initial major-context for participating RFs and BFs in each storyboard. This includes setting an initial position and status, accuracy of the behavior of the RFs and the BFs. This context is used before a training scenario starts, thus all forces are set in prepared positions.

2) When a training scenario begins, Locate-context always transitions to **Move-context**. Move-context is used when an agent of the RFs or the BFs is moving to a selected position. For example, the forces move from a base to an occupied resource for patrolling. Move-context has three sub-contexts for representing more detailed moving behavior: Scout, Entry and Occupy. Scout-context for the RF is applied when i) a RF begins to approach a BF, ii) the RF moves back to the appointed place after attacking the TF or iii) the local task of the TF is to attack a scouting RF. The RF moves slowly and along a concealed route with precautions in the Scout-context. When a RF reaches a building and a selected position is in the building, Entry-context is used for insertion movements for the RF, such as entering the building with utmost precautions. When an agent receives a trigger, the Move-context will transition to Attack-context or Defense-context.

3) When the RF detects the TF or the BF receives a trigger from the TF, the context of the forces transitions to **Attack-context**. The selection of the sub-context for the RF or the BF depends on the training level. For example, if the training level is novice, the RF or BF attacks at random. However, if the level is expert, the RF or BF is moving to an advantage position, while avoiding being fired upon. These behaviors are represented by four sub-contexts: HastyAttack, CounterAttack, OffensiveAttack and DefensiveAttack.

i) HastyAttack sub-context transitions from Defense-context or Move-context. This sub-context is used when the training level is novice or intermediate. This behavior indicates that the RF or BF is not prepared to defend. Other situations applicable to this context are transitioned from Entry-context. In this context, the RF or BF immediately attacks at that point.

ii) CounterAttack sub-context has several advantageous attacking positions. This context transitions from Move-context or Patrol-context. In this context, the RF or BF moves as quickly as possible to the nearest advantage position for attacking. The position may not be optimal but it might be better than a hasty attack.

iii) OffensiveAttack sub-context is used when the mission objective is to attack tactically and the RF or BF prepares for attacking. For example, when this context is applied to the RF who is on a lower side towards the TF, the TF may find it hard to detect the RF. The RF will be shooting while crawling towards the TF or moving towards a concealed position in order to take an advantage in attacking the TF.

iv) DefensiveAttack sub-context transitions from Ambush-context. The RF or BF is in a concealed position when transitioning to this context.

All of these attack-contexts transition to Defense-context or Move-context.

4) If the RF is attacked by the TF, the context of RF will transition to **defense-context** which has three sub-contexts: patrol, guard and ambush.

i) When a mission objective of the TF is to attack a critical resource and the training level is novice or the BF receives a trigger from the TF, Patrol-sub-context is used in these situations for the RF or BF. This context indicates that the force is poorly prepared for defensive action. The force patrols a common open area. The context will transition to the HastyAttack-context, in case of being attacked.

ii) The Guard-sub-context is selected when the training level is higher than intermediate or the BF receives a trigger from the TF. In this context, the force is prepared to be attacked, so that the force moves to a defensive position while avoiding being shot and transitions to CounterAttack-context.

iii) Ambush-context is used when a mission objective or task is to attack a critical resource and the training level is expert, or the BF receives a trigger from the TF. This context transitions only from move-context. When the force is being attacked or the RF detects the TF, the context will transition to DefensiveAttack-context. In ASGS, ambush has the same meaning as sniping.

Representation of behavior of the RF

A representation of behavior of the RF is developed considering the trainee course of action in each storyboard in order to place the TF under the conditions that address their training objectives and mission objectives. For example, a local task of the TF is to approach the building. The RF local task can be assumed to be to patrol around the building. The TF might detect the RF. The TF will shift to an advantageous position and then attack. Another task could be to ambush the TFs. In this case, the TF has to perform a hasty attack. Thus, the various scenarios can be strongly influenced by various RF behaviors.

The RF behaviors are represented by major-contexts. The major-contexts are subdivided into sub-contexts for the purpose of representation. The example behavior representations are described below. When the training level is novice, the RF behavior representation in CxBR is described in Figure 6.

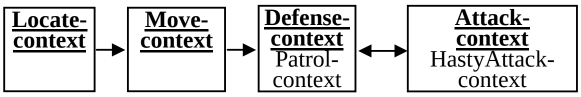

Figure 6: The RF context in novice level of the training

Before a novice level training scenario is executed, a context of a RF agent starts Locate-context. The Locate-context sets the position and posture of the RF. When the scenario starts, the Locate-context will transition to the Move-context in order to move to a patrol area or move into a building. When the RF reaches the patrol area in the first storyboard, the context of TF will transition to Patrol-context. Patrol-context is used to patrol a predetermined path around a critical resource (the building in this case). When the RF is attacked by the TF, the context of TF will transition to HastyAttack-context. The RF tries to attack immediately without tactical behavior.

When the training level is intermediate, the RF behavior representation in CxBR is described in Figure 7.

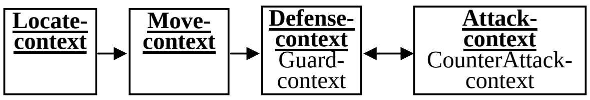

Figure 7: The RF context in intermediate level of the training

In the intermediate level of the training scenario, RF selects Guard-context as defense behavior and CounterAttack-context as attacking behavior. These mean that the RF behaves more tactically. However, the novice and intermediate level of the RF both call for attacks when they are attacked by the TF. This means that the RF will not attack unless they are attacked by the TF or BF. Thus, the TF can easily approach or enter the critical resources.

When the training level is advanced, the RF behavior representation in CxBR is described in Figure 8.

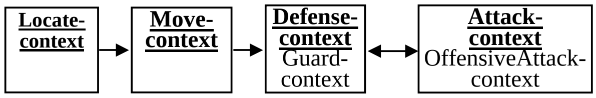

Figure 8: The RF context in advanced level of the training

The difference between the intermediate level and the advanced level of the RF is Attack-context. OffensiveAttack-context is selected in the advanced level. This means that when the RF detects the TF, the RF will carry out a preemptive attack against the TF. When the training level is expert, the RF behavior representation in CxBR is described in Figure 9.

In the expert level of training, the RF selects Ambush-context as defense behavior and DefensiveAttack-context as attacking behavior. These mean that the TF finds it hard to approach and enter the building. This is because the TF has difficulty in finding the RF and the RF does not wait until the trainee attacks the RF. Even if the TF finds the RF, the RF moves to the defensive attack position.

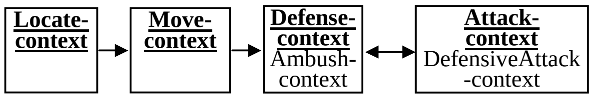

Figure 9: The RF context in expert level of training

DEVELOPING THE ASGS PROTOTYPE SYSTEM

SVS desktop is used as a training system to validate the method of generating scenarios in ASGS. SVS desktop is a virtual training simulation, especially for infantry combat training, working as Windows application software. SVS desktop uses scenario for controlling CGF. The ASGS prototype developed as a tool for scenario generation in the SVS desktop. The following section describes the relationship between the ASGS prototype and the SVS desktop system. Next, the basic function of SVS desktop is explained. Then input and output data is described as external design. Furthermore, internal design describes the means ASGS uses to accomplish scenario generation.

ASGS prototype system specification

The ASGS prototype is used in the training system: The training system is composed of three hardware devices: Desktop computer, input device and output device. Two software applications are installed in the desktop computer: the SVS system and the ASGS prototype. The ASGS prototype is programmed in the C language. The ASGS prototype generates scenario files, which are read into SVS system. An instructor inputs initial conditions through the ASGS prototype and can modify the scenario files and control the exercise through SVS system. The SVS system creates virtual battlefield and CGF forces. It then displays these through an output device. A liquid-crystal display is used as the output device in the training system. The TF makes decisions through an input device. A joystick is mainly used as input device that enables to fire the weapon and change the posture.

The following Figure 10 describes the system structure of the ASGS prototype.

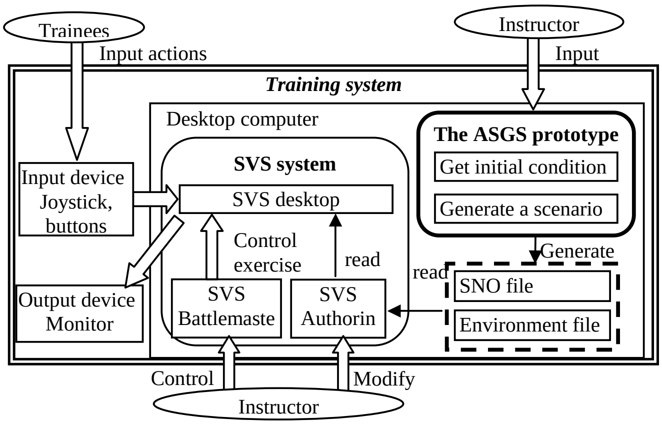

Figure 10: System structure of the ASGS prototype

The roles of the ASGS prototype, the SVS system and the user

This section describes the roles of the user, the ASGS prototype and the SVS system in the scenario generation process.

1) The user inputs following factors for generating a scenario: i) selects the initial conditions through the ASGS prototype, such as the training objective, mission objective, the training level, the size of RF and the strength of RF, ii) inputs the trigger for transition contexts in the SVS system during simulation runs, iii) selects the created scenario files in the SVS system, including initial positions of the TF and the weather conditions.

2) The ASGS prototype generates scenario in the following factors: i) provides the input menu of the training objective, mission objective, the training level, the size of RF, ii) generates RF and BF position, behaviors and waypoints in each training level which uses pre-installed CGFs in the SVS system, iii) generates the weather conditions in each level of the training, iv) generates the initial position for the TF and v) generates the trigger command selected by the instructor during simulation runs.

3) The SVS system provides training environments: i) provides CGF models with the basic behaviors for the RF and the BF, ii) provides the weather conditions and iii) provides pre-installed the terrains and buildings.

External design of the ASGS prototype

This section describes the method of input conditions and what result ASGS generates for an exercise. ASGS generates five scenario files including a SVS format scenario file, two environmental setting files, an initial position file for all levels of the TFs and a signal file for CGF behaviors. A terrain used in ASGS is prepared as a default map by the SVS system. The system uses the building as a critical resource. The building objects can be entered. Other objects are box objects which can hide the TF but which it cannot enter. ASGS constructs a storyboard that includes trainee course of action. Then, ASGS represents the RF and BF's actions with contexts.

Input and Output

The initial conditions are set by questions and answers through the ASGS prototype. The instructor from predetermined questions in this prototype selects the question item. The question items are shown in the following Table 8.

Table 8: Instructor input conditions for scenario generation

#	Question to instructor	Selection
1	Decide actions for the training objective	1: attack, 2: defend, 3: reconnoiter, 4: march, 9: quit
2	What is the target	1: building, 2: bridge, 3: military unit, 9:quit
3	Select the mission objective	1: Occupy the target building
4	Select the level of exercise	1: Novice, 2: Intermediate, 3: Advanced, 4: Expert
5	Select the scale of trainee force	1: platoon, 2: company, 3: battalion
6	Select the type of trainee force	1: infantry, 2: artillery, 3: engineer, 4: cavalry, 5: combined choices
7	Select the mode	1: automatic, 2: manual, 9: quit

Training objective assumes that learning how to attack buildings as critical resource. Thus, No.1 question is selected 1 (attack) and No.2 question is selected 1 (building). The mission objective is occupying the target building. This mission objective is user-entered in the ASGS prototype.

When the training and mission objectives are set, the prototype system created two storyboards areas as "in front of the building" and "includes the building" in the terrain. One storyboard is scouting the target building. Another storyboard is attacking the buildings. The first storyboard is not created when the training level is novice or intermediate. Contexts are used to represent these storyboards. Events and behaviors are developed for representing these contexts in the SVS SDT files.

Internal design of ASGS prototype system

This section describes the internal design of the ASGS prototype. The following is a definition of the functions. Also described are the CGF movements such as development of the context in the SVS SDT, and setting path and generating a SNO file.

Figure 11 describes the module structure of the ASGS prototype. There are three types of modules in the ASGS prototype. They realize environmental setting, storyboard and CxBR. InitDataset module including its child modules are used to generate environmental setting and initial setting of RFs. SetrbdCgfScenario module and its child modules are used to generate CGF models with CxBR paradigm. Other child modules of Main module are used in order to correspond to the SNO file.

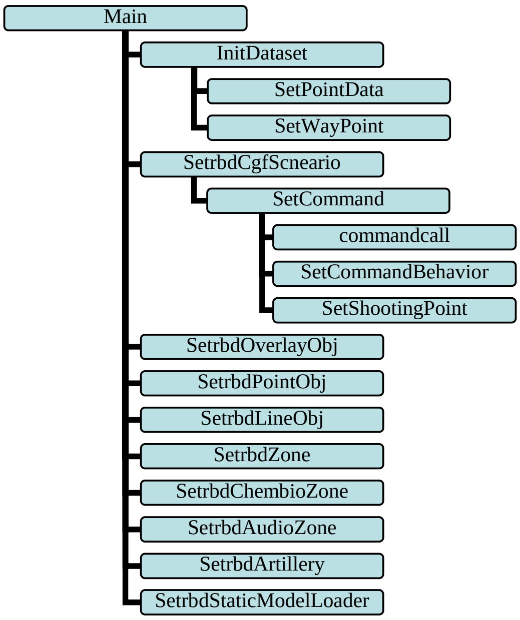

Figure 11: The module structure of the ASGS prototype

Table 9 shows the list of the function modules in the ASGS prototype. The asterisk (*) indicates objects not necessary to set effective information for a scenario. However, the SNO file needs to define the frame even with such objects, otherwise, the SVS system does not read the scenario.

Table 9: The list of the function modules

Module name	Function
InitDataset	The definition of the number of waypoint, the maximum number of the human entity, accuracy of entity behavior, initial position and initial movement. Moreover, setting environment. This module has two sub-module: "SetPointData" and "SetWayPoint"
SetrbdCgfScenario	The definition of the signal list, heading and position of the CGFs, selected path, the relationship of sides, carrying weapon type, position and movement and define contexts. This module has a sub-module: "Setcommand"
SetPointData	The setting of the initial position of the forces in the training level
SetWayPoint	The setting of the waypoints for the RFs in each training level
SetCommand	Sets command to each CGF. This module has three sub-module: "commandcall", "SetCommandBehavior" and "SetShootingPoint"
Commandcall	The definition of the basic command for CGFs. There are 19 types of the basic command
SetCommandBehavior	The definition of the action sequence for CGFs in each training level
SetShootingPoint	The definition of the shooting points for CGFs. There are nine zones of the shooting points
SetrbdOverlayObj (*)	The basic definition of the friendly force and the RFs
SetrbdPointObj (*)	The definition of the position, size and color of point setting
SetrbdLineObj (*)	The definition of the position of the points in each line
SetrbdZone (*) SetrbdChembioZone (*) SetrbdAudioZone (*)	The definition of the position, size, color and height of the zone
SetrbdArtillery (*)	The definition of the artillery setting
SetrbdStaticModelLoader (*)	The definition of the type, position of the static model

When the ASGS prototype starts to create the storyboard, the frame of the terrain field will select from critical resources in the terrain. This frame of the terrain field uses the default area of the storyboard. The basic training objectives of the infantry forces are assumed to be four objectives: 1) Learning how to attack, 2) Learning how to defend, 3) Learning how to scout and 4) Learning how to march. When the training objective is learning how to attack or learning how to scout, the frame of the terrain for a storyboard is separated from the default area as "in front of the critical resource" and "includes the critical resource". The reason is that there are two different tasks that are to approach the target and to attack the target. When the training objective is learning how to scout, the storyboard does not separate from two areas. If the training objective is learning how to march, the terrain is a more important factor to the training, thus the area does not necessarily include critical resources. Even if the training objectives are learning how to attack or scout, the storyboard of “in front of the critical resource” is not necessarily created when the training level is novice or intermediate.

An agent of the RF has only one selection of the sub-context in each major-context as far as the local task of the storyboard is simple. Table 10 describes the initial selection of the sub-context of each major-context in each level of the training. The initial selection of the context does not include the trainee action.

The ASGS prototype generates two files: 1) scenario SNO file that includes initial position and behavior representation for TF, BFs and RFs and 2) environmental condition file that includes weather, time and day, wind etc. SVS desktop has a-priori files that are terrain file and CGF objects file includes behaviors for the basic commands. The prototype uses these files.

TEST AND EVALUATION

The ASGS prototype system is validated by the results of a example scenario with a training objective and a mission objective. There are three objectives in the evaluation: 1) Evaluating whether a reasonable and credible scenario is developed on SVS desktop by the ASGS prototype. In military training, developing a reasonable and credible scenario is a very important point for the scenario development tools. The tool needs to create a suitable scenario for the training objective. Otherwise, the tool is useless. 2) Evaluating whether multiple credible scenarios for the same input conditions are equivalent. The scenarios have to be validated for their equivalence in order to provide multiple credible scenarios to trainees, and 3) Validating different levels of training for the environment. The environmental conditions influence the level of training. In these experiments, the opinions from experts are obtained for validating synergistic effects in scenario and environment conditions.

In SVS desktop, the scenario developer can change all information about the scenario, environment and initial position. This information is saved as individual files under the SVS folders. These files can be overwritten or selected from several files in order to use other SVS desktop computers. These files do not depend on whether the file is created in SVS desktop or not. Thus, the files generated by ASGS prototype system can be edited through the SVS desktop. The test can confirm this by changing the weather setting, add an event in a path and change initial position.

Specific experiments

Following the previous objectives in evaluation, multiple exercises with the same training conditions were used to verify the variety of reasonable and credible scenarios. The test case in this experiment consisted of three levels of training exercises and two scenarios at each level for a total of six test cases. There are three objectives in each level of these experiments: 1) The objective of the novice level of experiments is to validate it for generating multiple scenarios under the same environmental condition, 2) The objective of intermediate level experiments is to validate it for generating equivalent scenario under the same initial position of the TF and the different environmental conditions and 3) The objective of expert level of experiments is to validate the representation for generating clearly different levels of scenarios.

The estimated exercise durations are less than thirty minutes each. Test results were presented to three experienced military experts for their evaluation.

An evaluation sheet was provided to the evaluators. The form of the evaluation sheet is questions-and-answers and the experts evaluate throughout the experiments. The questions are described in the following Table 10. The answers to the questions can be “yes”, “no” or “don’t know”. One questionnaire was used to cover the six experiments shown to each of these experts.

Table 10: Question for the exercises

No	Question
1	The scenarios at each level of the exercise are equivalent
2	You can recognize that the levels of the exercises are different
3	The RFs (CGF) behave with reality
4	The exercises are effective for the trainee
5	The environmental conditions influence the exercises and are appropriate for the exercises.

For evaluating the reality of scenarios, the following five factors are evaluated by validation subjects (the experienced military officers): 1) the exercise is realistic, 2) Two different scenarios of same level are equivalent, 3) scenarios of different levels can be recognized, 4) the scenarios are effective for the trainee and 5) the environmental conditions influence the scenario. The experiments with these officers do not constitute an in-depth validation. Nevertheless, it is an evaluation of the effectiveness of the ASGS.

Evaluation of the Experiments

Three military experts evaluated these experiments. All of the answers for the questions are positive except one answer for question 3. A RF fires behind them without turning around. This does not always happen, as other two experts did not mention it. Without this problem, the experts evaluated these exercises to be generally realistic situations and are acceptable for training within limited situations. The RFs are set closely to the target building and the training level changes the forces behavior. This is effective for the trainees. The fog influences the visibility for the trainees. The time of day, such as morning or evening, the weather condition such as rain, sunshine or snow influence the brightness. These factors are very important for military activities and effectively influence the difficulty of training exercises in the scenario created by the ASGS prototype system.

In the novice level of training, three experts evaluated the experiment. The answer from question 1 finds that changing start position but not changing the location of the target building is effective for representing multiple scenarios. However, the answer for question 3 by a veteran evaluator states that the CGF shoots behind itself without looking around. The TF may misunderstand the RF behavior. To prevent this unrealistic behavior, the aiming place to fire should be defined more finely.

The result of the novice level of experiments is that changing weather condition can be effective for representing different levels of training. The behavior of the RF is also different and appropriate for representing level than it is for novice. The answer to questions 2 and 5 shows the evaluation of this level of experiments. Increasing RFs and changing environmental conditions can be recognized as more difficult than novice level. Thus, the trainee can be trained by the exercises in a different situation.

The result of expert level of experiments is that the weather conditions are too severe for a single soldier. Even when executing experiment under novice weather conditions, there are too many RFs around the building. Thus, the military experts said this level of exercise should represent team training for the TF. The military experts' answers for questions 2 and 5 show the environmental condition are effective in recognizing these experiments are the most difficult level.

Some Comments on the Prototype Evaluation

The ASGS prototype automates the scenario development process for training exercises. This has the effect that it is able to create different but equivalent scenarios for the TF. The different factors are as follows: 1) The initial position of TF, 2) The location of the RFs and 3) The environmental conditions. Although these factors provide different scenarios, following factors are the same: 1) The behavior of the RFs, 2) The size of the RFs and 3) The visibility. These factors can provide equivalent training for the TF.

In the ASGS prototype system, the mission objective is "occupy the target building" that the TF must defeat the RFs completely around the target building. When the TF reaches the target building after it defeats all RFs, the scenario ends. The expert commented that the trainee is less motivated with this mission objective. Because there is not enough concealment around the target building, the trainee cannot easily approach the target building.

The initial stage of the ASGS prototype system provides brief training and mission objectives. Furthermore, the ASGS prototype system does not use static objects such as trees or oil drums for concealment. When attacking is a training objective, concealment objects are very important in the exercise. The static objects should be included in the scenario generation. Another issue is that the ammunition is unlimited in the ASGS prototype system. The actual situation of attacking a building by a platoon force, the ammunition is limited and is usually less-than-normal combat situation because of their quick attack.

There are some remaining issues in the scenario generation such as providing objects in detail or to set static objects which represents more realistic environments. However, overall, the scenario events, the RF behaviors, the location of the RF and environmental conditions are effective and suitable for an attacking training exercise. Therefore, the behavior representation of the RFs through contexts, spotting troops in positions using storyboards and setting of environmental conditions work correctly. In the future, ASGS can be evolved with more training objectives and more mission objectives.

SUMMARY, CONCLUSION AND FUTURE WORK

The ASGS prototype system successfully implements the idea of storyboards and CxBR. The test results showed the possibility of automatically generating scenarios that are different but equivalent. However, the ASGS prototype system is limited, generating few training and mission objectives. The instructor has to input point data (e.g. firing points, waypoints) to the ASGS prototype. CGF behavior representation in SVS desktop is simple. SVS desktop does not make the most of CxBR ability. Thus, this research needs to be continued further. It includes a greater variety of behavior representation, the kind of training simulation, mission and training objectives and other factors.

The concept of ASGS can be used for different military training. For example, the infantry in ASGS prototype can transition to a submarine in naval force training. A warship can detect the submarine in the shallows that can equate to a wide-open area for the infantry. The behavior representation can also transition to the warship.

In this paper, the ASGS prototype generated squad scale of exercises. However, ASGS is able to scale up as the size of the TF increases. Even if the TF is a platoon or larger forces, the trainee course of action, as well as storyboards and CxBR for the RF, will not change during ASGS. ASGS regards the TF as a platoon or larger TF.

ASGS only considers course of action for a part of the team training. In the near future, more objectives should be considered. For example, the attacking scenario developed in the ASGS prototype system can be divided into three detailed scenarios: 1) when a hostage is in the target building, the exercise includes deciding whether to attack or not, 2) when there is no hostage but the building is a critical resource such as a military installation and the trainee should decide to attack carefully, and 3) when the mission is just to occupy the area, the trainee will observe whether there is artillery nearby or not. Thus, the motivation of the mission or training should be considered with scenario generation.

When a scenario is generated, the events and actions should be provided to the instructor through the ASGS GUI. At this point, the instructor does not get any information about events and actions through the ASGS prototype system. Therefore, if the instructor wants to get information of scenario, he has to confirm through SVS desktop. This is time-consuming work. Also, the instructor cannot explain the situation before the exercise begins. When the information can be obtained or listed by ASGS, the instructor can easily revise or edit the scenario.

ASGS is using default terrain and objects provided by the SVS desktop. ASGS does not recognize the key terrain or critical objects by itself. Therefore, an instructor has to set the information of object location and terrain border. ASGS should provide an interface for selecting a target, recognizing or creating terrain.

ASGS may apply to other kinds of training simulation such as driving simulator or flight simulator. ASGS has a great possibility of scenario generation not only military training but also many other field of training simulation.

REFERENCES

Cloud, D. J. and Rainey L. B. (1998) Applied modeling and simulation: An Integrated Approach to Development and Operation. Space Technology Series, *McGraw Hill Co. Inc*, 1998.

Davis, P. K. (2005) New Paradigms and new challenges. *Proceedings of the 2005 Winter Simulation Conference (WSC), 2005.*

National Research Institute for Earth Science and Disaster Prevention (NIED). (2005) *Special project for earthquake disaster mitigation in urban areas, Final report.* May, 2005.

NATO Research and technology organization. (2005) RTO TECHNICAL REPORT TR-SAS-027 Handbook on the Analysis of Smaller-Scale Contingency Operations in Long Term Defence Planning. *NORTH ATLANTIC TREATY ORGANISATION (NATO)*, February 2005.

The American Heritage Dictionary, Fourth Edition. (2000) *Published by Houghton Mifflin Company in 2000.* Retrieved May 23, 2006 from http://dictionary.reference.com

The Defense Advanced Research Projects Agency (DARPA). (2006) Future Areas of Interest. Retrieved May 23, 2006 from http://www.darpa.mil/dso/future/faoi.htm