Performance- Based Advancement Using SCORM 2004

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ABSTRACT

The Advanced Distributed Learning (ADL) vision encompasses the use of scenario-based simulations to provide a rich environment for training complex tasks. At the same time, it introduces a complex assessment environment, which creates challenges in the accurate and efficient diagnosis of student needs as frequently student behaviors can be interpreted in several ways. Diagnosing student learning needs, consequently, becomes problematic. Unfortunately, there are currently no best practice guidelines for extracting and making use of performance data from a simulation-based training environment. However, methods that address these challenges are required for the successful integration of simulation-based training into the ADL Initiative.

The research described in this paper is investigating the development of a scenario-based performance assessment method that leverages the Shareable Content Object Reference Model (SCORM), while using information on trends to isolate individual learning needs. Specifically, SCORM 2004 specifications enable a single Shareable Content Object (SCO) to be linked to (i.e., to set a value of or the status of) multiple learning objectives. Although the potential impact of this capability for assessment has not been widely recognized to date, it provides a means to interpret relatively complex responses in scenario-based training in terms of all of the learning objectives that may be implicated by a given action. The methods developed under this project will support changing the measures that reflect a student's mastery of the underlying learning objectives as a result of study, practice, and forgetting. Further, hypothesis-testing methods will be employed to resolve ambiguous diagnoses of learner needs.

These methods are being applied to the development of an ADL prototype in the context of Marine Air Ground Task Force (MAGTF) command and control training. The *MAGTF XXI Tactical Decision-Making Simulation (TDS)* is being employed as the simulation-based training environment. The proposed paper will describe this research and its application to the development of a simulation-based training application for the MAGTF commander.

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INTRODUCTION

The Advanced Distributed Learning (ADL) initiative is leveraging significant advancements in computer simulation, visualization, networking, and learning technologies to aid the development of robust, scenario-based simulations to provide a rich environment for training. Simulations provide a safe, controlled setting that approximates actual work situations in which new knowledge can be applied, and skills and abilities can be developed and honed. Although this robust training environment is potentially richer, it is a more complex and confusing assessment environment.

Unlike traditional paper-and-pencil tests or computer-based multiple choice tests that provide the student with a specific set of potential responses from which to choose, scenario-based simulations provide a less constrained environment in which the student can respond with a wide range of behaviors. Often, these behaviors can have any of several interpretations, resulting in differing diagnoses of learning needs. The following is a simplified example to illustrate this point.

Suppose that during a scenario-based training exercise, a student who has been given instruction on the use of simple hand tools tries to use a hammer to connect two boards using wood screws. Such an action might indicate that the student misunderstands the use of screws and a screwdriver. But does the action also imply that the student does not understand the use of a hammer and nails, or only that he/she has over-generalized the function of a hammer to connect two boards? In such a case, studying the use of hammers could be considered less relevant than studying the use of screwdrivers. Or perhaps the error does not reflect misunderstandings of hand tools at all, but only that the student mistakenly thought the screws were nails, i.e., a random, perceptual error. The point of this example is simply, for any given action in a scenario-based training exercise, there are frequently numerous possible learning-need diagnoses.

We have developed a performance assessment methodology, Performance-Based Advancement, for use in simulation-based training environments to:

- Extract and make use of performance data,
- Interpret student actions, and
- Resolve ambiguity in diagnosis.

To explore the issues involved with implementing this methodology, we are currently developing a prototype using the *Marine Air Ground Task Force (MAGTF XXI)* Tactical Decision-making Simulation (TDS), developed by MÄK Technologies, Inc., as the simulation-based training environment. The prototype will provide a testbed for investigating this methodology and evaluating its effectiveness in reducing training time and improving learning. The remainder of this paper will describe:

- Prior research in the areas of performance assessment and Advanced Distributed Learning,
- The Performance-Based Advancement Methodology, and
- Plans for testing and evaluating the effectiveness of this method.

BACKGROUND

Performance-Based Advancement prescribes a means for automating student performance evaluation in a simulation-training environment. This method provides a means of diagnosing the root cause of student error to support the provision of tailored instruction. By enabling the student to progress through a training course based on his or needs, rather than advancing according to a pre-defined timeline, training time should be optimized. This methodology was developed based on prior research conducted in the areas of adaptive learning and simulation-based training. Additionally, this methodology leverages the progress made by the Advanced Distributed Learning (ADL) initiative, in particular, the Shareable Content Object Reference Model (SCORM®) 2004. The following paragraphs present these works.

Advanced Distributed Learning (ADL) Initiative

The ADL Initiative was created by the Office of the Under Secretary of Defense for Personnel and Readiness (OUSD P&R) to oversee the development and implementation of learning technologies to provide instruction tailored to individual needs and delivered cost-effectively, anytime, anywhere (http://www.adlnet.gov/aboutadl/index.cfm). In order to promote re-use and sharing of instructional content and compatibility of instructional systems, the SCORM® standard was developed. SCORM employs an object-based approach to specify the development and delivery of instructional content to enable interoperability of these objects across multiple delivery environments. (For detailed information on ADL and SCORM, please visit: http://www.adlnet.gov.)

SCORM 2004, the current standard, provides a means of specifying the sequencing of instructional content to provide the student with a learning experience tailored to his or her needs. Specifically, content can be provided as relatively small, web-available "chunks", or Shareable Content Objects (SCOs). Using the SCO sequencing capabilities provided by SCORM 2004, the sequence of content can be adjusted according to the student's learning needs as reflected by his/her performance. Additionally, SCORM 2004 allows for learning objectives (LOs) to be linked to a single SCO (prior versions of SCORM only allowed for a single LO to be linked to a given SCO). Our method leverages these capabilities to evaluate student performance in complex, simulation-based environments through the ability to associate a single student action with multiple LOs and either adapt the scenario, or select a new scenario, that focuses on the LOs to enable efficient diagnoses of competing causes of student errors.

Adaptive Learning

One of the goals of this performance assessment methodology is to provide a means of providing instruction that focuses on the individual student's needs--in other words, to deliver adaptive learning. Prior adaptive learning research (Perrin, Dargue, & Banks, 2003; Perrin, Banks, & Dargue, 2004) indicates that dynamically updating estimates of a student's mastery of a domain and using these estimates to adjust sequencing of content and pace of study can improve learning performance. The investigation of this capability (Perrin et al., 2004; Perrin et al., 2003) involved a training effectiveness study of SCORM 2004 adaptive learning concepts.

Within this study, students first studied the declarative knowledge necessary to perform within the problem-solving situations. Next, the situations were described in text, and the trainee was provided several alternative courses of action. Each incorrect action was linked to the underlying learning objectives that might be implicated by the response. When a trainee selected one of these incorrect actions, the status of the corresponding learning objectives was set to "not satisfied" and appropriate remedial material was presented.

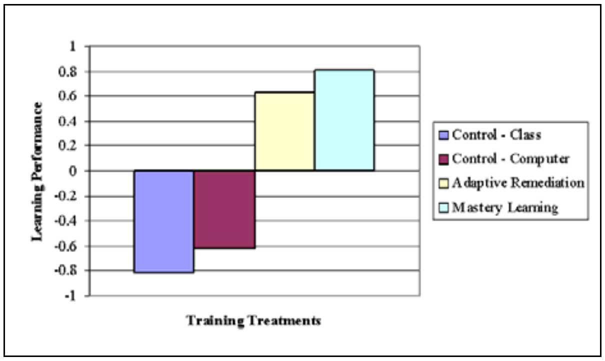

Figure 1. Training Effectiveness Results

The study demonstrated significantly improved learning performance (Figure 1), even though the course was relatively brief (1.5 hours) and the problem-solving skills were relatively simple. As opposed to the simple, "satisfied - not satisfied" dichotomy used in this study, remediation actions based on performance trends may provide a more efficient approach to content and scenario sequencing. These learning performance estimates distinguish random or chance effects from systematic variation, (e.g., that due to either learning or forgetting).

Scenario Based Performance Assessment

Our method seeks to provide a means of implementing automated performance assessment of student behaviors in a complex simulation environment. In effort to provide control over the breadth of behaviors that might be elicited during the performance of a simulation-based training scenario, the construction of the training scenarios is aligned with the development of the performance metrics. This approach is based on the Objective Based Training (OBT) and Scenario-Based Training (SBT) methods previously developed.

OBT and SBT provide a systematic method for evaluating training performance (Acton et al., 2001; Cannon-Bowers & Salas, 1998; Cannon-Bowers et al, 1995; Smith-Jentsch, Johnston, & Payne, 1998). OBT involves the development of scenarios that provide training events or opportunities to develop knowledge, skills, and attitudes that support training objectives of interest. There are five steps involved with OBT:

1. Plan,
2. Generate,
3. Brief,
4. Execute-data collection/assessment, and
5. Debrief/Perform After Action Review (AAR).

Scenario-Based Training (SBT) provides systematic linkages between scenario design, development, implementation, and analysis to provide training that focuses on the enhancement of individual and team performance (Oser, Cannon-Bowers, Salas, & Dwyer, 1999). SBT addresses both cognitive and behavioral elements of task performance. Performance measures that support diagnosis of the mastery of specific training objectives are enabled by data obtained from the system. In the case of both OBT and SBT, event triggers can be used to automate the collection of performance data during execution and support training evaluation during debrief (Cardinal et al, 2004).

High Level Architecture – SCORM Integration

Implementation of our performance assessment method requires the extraction of data from the simulation-based training environment. As this approach involves the use of SCORM 2004, a means for translating data from the simulation environment into SCORM 2004, and conversely from SCORM 2004 to a standard recognized by the simulation-based training environment (e.g., High Level Architecture – HLA, Distributed Interactive Simulation – DIS) is required. Our current prototype development efforts leverage a prior investigation that developed an automated instruction prototype to demonstrate the integration of HLA and SCORM.

This HLA-SCORM prototype provided practice and performance data collection and feedback on an Instrumented Landing System (ILS) F/A-18 approach and landing. The prototype implemented a shareable content object (SCO) that served as a "virtual flight instructor" for the student. This Virtual Instructor SCO initializes the simulation, then monitors and evaluates the student's performance of the task. It then uses SCORM conformant methods to send the student's evaluation results to the Learning Management System (LMS). Figure 2 illustrates the use of HLA and SCORM specifications to communicate student performance data.

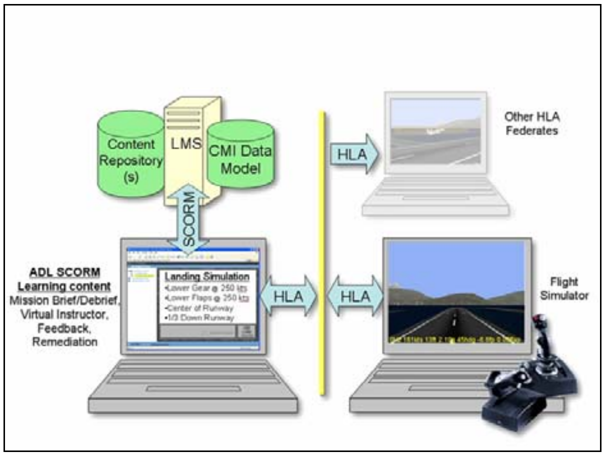

Figure 2. HLA/SCORM Integration

The HLA/SCORM integration approach developed during this effort is currently being leveraged by our current prototype effort that involves the use of an HLA simulation-based training environment (*MAGTF XXI).* Automated performance measures are being developed to obtain data from *MAGTF XXI* via HLA protocols, calculate the metrics, and dynamically update the scores of the LOs that have been associated with the behavior evaluated by the metric via the SCORM 2004 protocol.

Marine Air Ground Task Force (MAGTF) XXI

MAGTF-XXI (Figure 3) is a real-time, tactical simulation developed under the U.S. Marine Corps (USMC) Program Manager Training Systems (PM TRASYS) Tactical Decision-making Simulation (TDS) program to facilitate expeditionary warfare training. The trainee can assume the role of a Marine Expeditionary Unit (MEU) commander or staff member. We are using *MAGTF XXI* in our current prototype effort to provide the simulation-based training environment. For this effort, the trainee assumes the role of a MEU company commander.

Figure 3. MAGTF XXI User Interface

MAGTF XXI can be run in a single- or multi-player mode. Although the current effort is focused on individual performance assessment, the simulation is being used in multi-player mode. The trainee will manage the deployment of assets and controlling maneuvers to perform an in-stride breaching operation in the training scenarios being developed for the prototype.

PERFORMANCE-BASED ADVANCEMENT

Performance-Based Advancement is an approach for automating the assessment of student performance that enables the efficient evaluation of student LO mastery and the delivery of targeted feedback and remediation. This method leverages the sequencing and navigation capabilities of SCORM 2004 and prior HLA-SCORM integration approaches as discussed in the previous section.

As briefly mentioned in the Background section, until the release of the 2004 version of SCORM, SCOs were linked to a single, "primary" LO. However, current SCORM 2004 standard provides for a SCO to be linked to (e.g., to set a value of or the status of) multiple LOs. The potential value this capability provides for learner performance assessment is the premise for our method. Basically, it means that a single student action can simultaneously provide information regarding the mastery of multiple LOs. Additionally, SCORM 2004 permits the use of scaled scores (e.g., 0 to 1.0) to reflect learning objective mastery, so that information may be accumulated over repeated actions, as well as from multiple sources.

The Performance-Based Advancement method involves five steps:

1. Update scores of LOs related to student response
2. Provide weighted updates to these scores based on the significance of the action to the estimate of mastery of the LO
3. Compare LO scores to pre-defined thresholds for student mastery, hypothesis-testing, and remediation
4. Adapt scenario to actively test learner-need hypotheses
5. Act on the most strongly supported hypothesis to provide an individualized learning opportunity that include(s):
    a. Feedback,
    b. Selection of scenarios appropriate to performance, and optionally
    c. Remediation to declarative information covering LOs that fall below remediation threshold.

The following is an example that explains this capability. Consider a situation in which at the completion of a SCORM-2004-based, self-study and testing, a trainee's estimated mastery of six LOs might look something like Figure 4. The trainee then begins a follow-on scenario. If the trainee then makes an error, this learner's profile of LO scores might be updated to look like Figure 5. A second mistake, without a correct response on a behavior involving LO "a" would further reduce the scaled score for this LO.

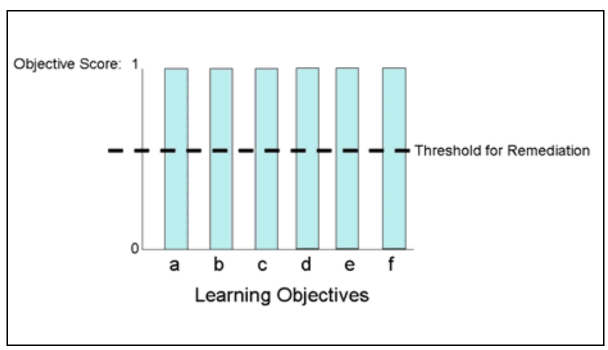

Figure 4. LO Scores at Completion of Initial Testing

Often, a given performance error will have numerous interpretations. That is, a given error might not be limited to updates on only LO "a", as described above, but rather, other LOs may also be implicated. For instance, misunderstandings or the forgetting of the facts, rules, and procedures might produce learning performance errors. Additionally, the root cause may be due to factors beyond the scope of training (e.g., momentary lapses in attention, distraction from an encounter earlier in the day, etc.).

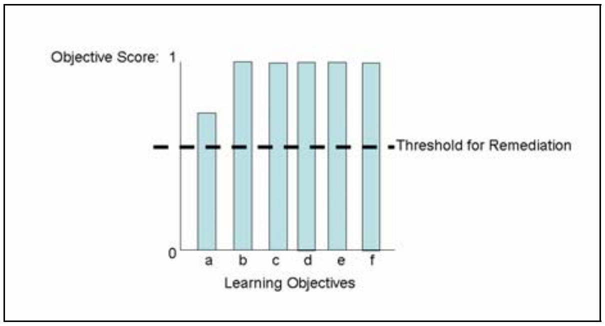

Figure 5. LO Scores after Error

As a response to this ambiguity, an average score is often calculated. A moving average can be expected, over the long-term, to yield an unbiased estimate of the true score for each of the LOs. That is, over sufficient time, averages based on randomly selected scenario-based training exercises could be expected to differentiate among competing root causes. Such an approach, however, may unnecessarily extend training time. By random selection of scenarios, it may be some time before sufficient data are available to distinguish among different root causes of an observed error.

A more efficient method of diagnosing learning-needs may be to actively identify and test learning-needs hypotheses. Conceptually, this amounts to setting a second threshold on the LO scaled score. Thus, performance errors would first move the scaled score for a LO below a hypothesis-testing threshold (Figure 6). In effect, the trainee's mastery of the related objectives would be suspect and the system would seek to resolve the uncertainty as to the root cause of the problem.

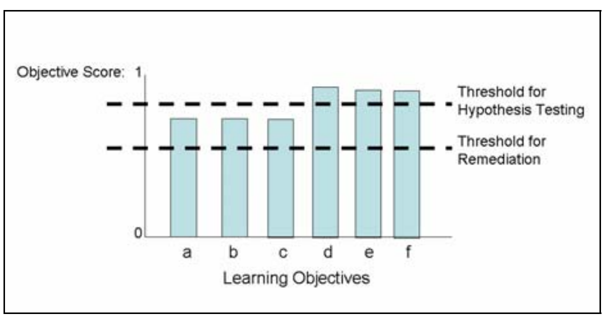

Figure 6. LO Profile with Hypothesis Testing Threshold

Where only one LO is implicated, "a" for example, exceeding the hypothesis-testing threshold would have the effect of scheduling additional scenario exercises involving application of the declarative knowledge learned under this objective. If the trainee continued to make mistakes, random or chance factors could be ruled out, and remediation on the content covered under objective "a" would be provided.

This hypothesis-testing capability operates somewhat differently where multiple objectives are implicated by a performance error. Consider an error in which all six objectives are implicated. The scores of "a" through "c" could be decremented to a point below the hypothesis-testing threshold (objectives "d", "e", and "f" would stay at zero, with no evidence of mastery).

PROTOTYPE IMPLEMENTATION

Although the SCORM 2004 specifications provide for the capability to support this method, a proof-of-concept implementation is required to verify and assess the full capabilities of these specifications. The development of a prototype to test the ability to implement this methodology with SCORM 2004 is described in the following.

Problem Domain Selection

The *MAGTF XXI* simulation was selected for the implementation of this prototype because it provides a complex simulation environment in the context of a realistic military task. Additionally, interface components for collecting and exporting performance data via the HLA from *MAGTF XXI* to a learning management system (LMS) via SCORM were already under development.

For the prototype, the training scenario focuses on the task of commanding an in-stride breach mission. The in-stride breach mission was selected because of the below features.

- Only a limited number of *MAGTF XXI* commands are required
- Scenario objective and boundaries are well-defined
- Involves simple and straightforward processes that can be challenging to execute
- Simple scenario requires minimal student time to assess the situation
- Maximum re-use as most people will need to try several times before achieving success
- Limited duration is amenable to demonstration and future training effectiveness experimentation

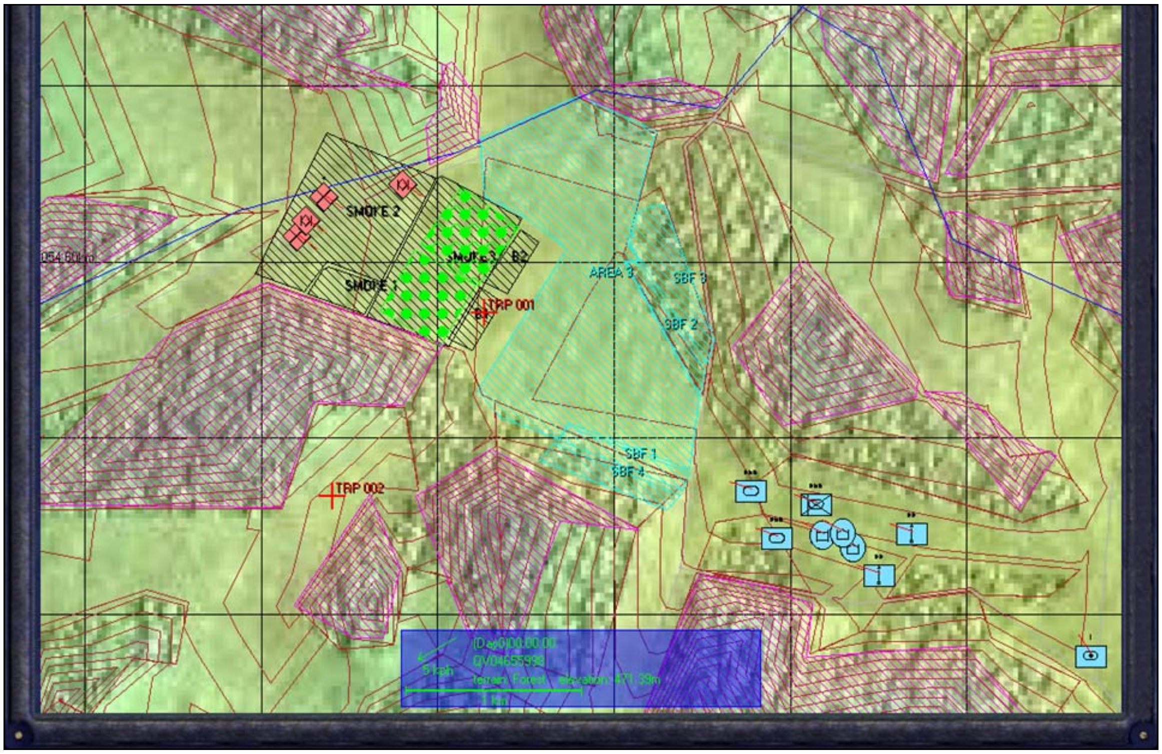

Figure 7. Breach Scenario Interface

For the prototype, the student assumes the role of a commander of a mechanized infantry – tank team. The student receives a pre-brief in which he or she is assigned a mission to conduct an in-stride breach of an obstacle. The exercise begins with the infantry-company team that is comprised of one tank and two mechanized platoons, making way to achieve an objective position. The student is informed, prior to commencing the scenario that an enemy minefield has already been identified and must be breached. The student is also informed that bypassing the obstacle is not an option.

The enemy strength is estimated to be one to two T-80 tanks and one to two BMP infantry fighting vehicles. The company has a direct support artillery battery as well as its organic mortars for indirect fire support. The company has three engineer vehicles that can breach the minefield.

Content Structure

Several different roles for the student and several different training tasks were considered before we selected the final alternatives for this study. We selected the role of a commander of a mechanized infantry-tank company. The task we identified was to conduct an in-stride breach of a minefield.

This task and role selection has several advantages for the purpose of this research. First, the scenario objective and boundaries are relatively clear. The option of bypassing the minefield is excluded from consideration by selecting an area bordered by relatively inaccessible terrain and introducing time constraints. Simply put, there is not enough time to bypass the minefield. Rather, trainees are required to identify the best approach routes and apply the appropriate tactics and actions to breach the minefield with minimum losses. Second, the task duration is relatively brief, permitting iterative practice sessions that will be necessary to demonstrate learning hypothesis testing and improvements in performance. Third, although the breaching procedure is relatively well defined, it is challenging to execute. It requires both initial, brief planning and continuing, time-critical problem solving as the scenario unfolds. Given the complexity and dynamic nature of the scenario, even experts can “fail”.

For the student population, we selected novices, both with respect to their experience with *MAGTF XXI* and as a unit commander. This selection assures a ready supply of trainees for formative evaluations during the development of our prototype. Perhaps more importantly for our research, it creates a situation in which many errors had at least two competing hypotheses by default. Specifically, many errors could implicate either a lack of understanding of the *MAGTF XXI* user interface or a lack of understanding of the tactical action that was required. So, for example, if students do not launch smoke rounds to obscure the movement of their units, the root cause might be a lack of knowledge/recall about how to launch smoke rounds using the *MAGTF XXI* interface or a lack of knowledge/recall of what they should do.

Additionally, early in training, errors of omission in particular may result from inadequate cognitive capacity of the trainees to initiate actions that they know they should execute and that they know how to execute. That is, based on a considerable body of research on the development of expertise (e.g., Anderson, 1993; Newell, 1990), we can expect initial performance to be slow and error prone, simply because the trainees are using a declarative form of the problem-solving skills. So, for example, students who know how to launch smoke rounds and understand that they should, may not, simply because they are preoccupied with low level actions like establishing routes of travel. As training continues, we can expect these lower level skills to become more proceduralized, permitting the students to focus attention on more complex decisions.

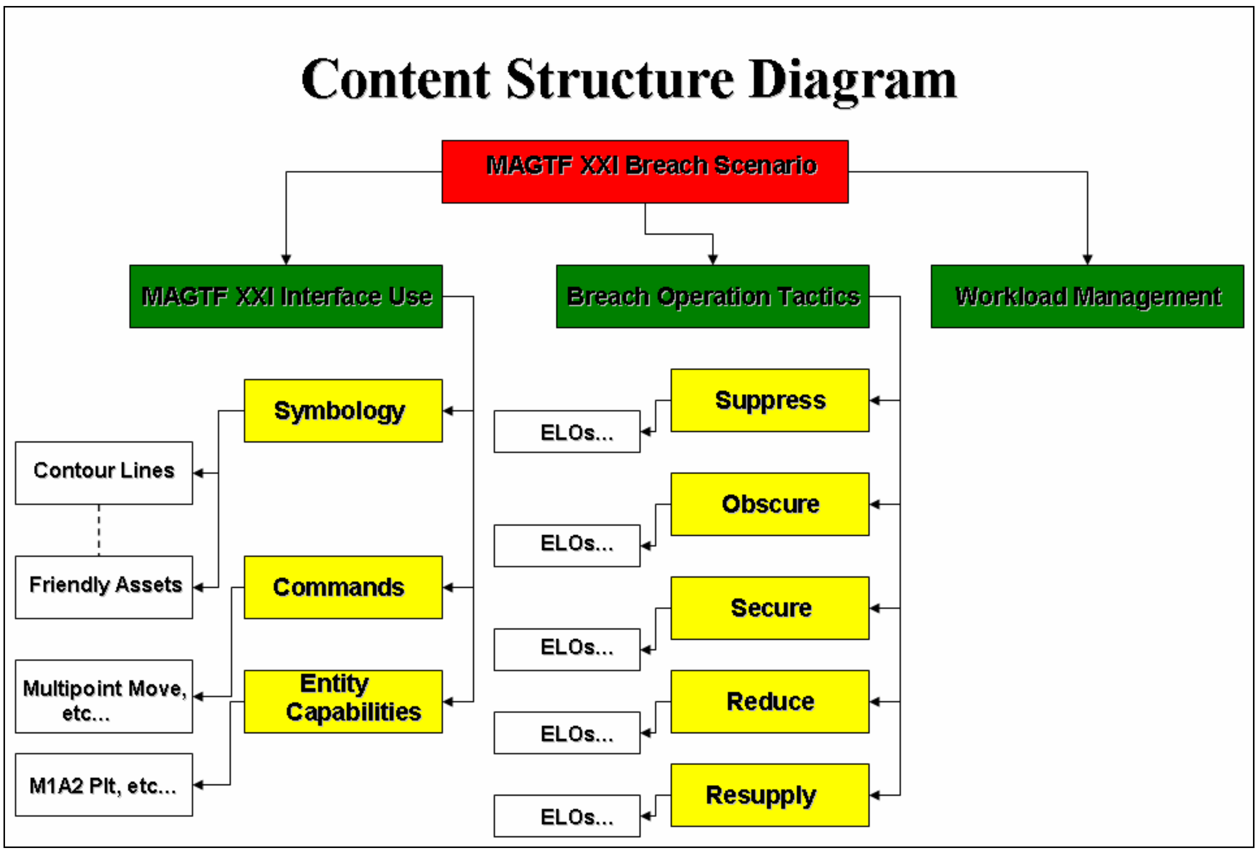

Figure 8. Content Structure Diagram for Prototype

With the addition of workload or capacity as a root cause of performance issues, many errors will have at least three competing explanations – a lack of mastery of the *MAGTF XXI* user interface, a lack of understanding of the proper tactical response in a given situation, or a lack of capacity to perform the action. The content was structured to reflect these three root causes, with aggregations for training *MAGTF XXI* menus, commands, and displays; one for training strategies and tactics for performing a hasty breach; and a final one involving the execution of *MAGTF XXI* scenarios to practice and proceduralize the skills involved. Each of the primary aggregations was further divided into sub-aggregations and Shareable Content Objects (SCOs). Figure 8 shows a partial content structure diagram for this prototype course. Overall, the content was organized into eight sub-aggregations and 39 SCOs.

Performance Measure Development

The authors are in the process of specifying the performance measures for the scenarios. This process began with the analysis of the breaching operation mission as performed in the *MAGTF XXI* simulation. Both optimal actions and common errors are being identified. The performance measures are being defined to permit the evaluation of actions using a logic-driven approach.

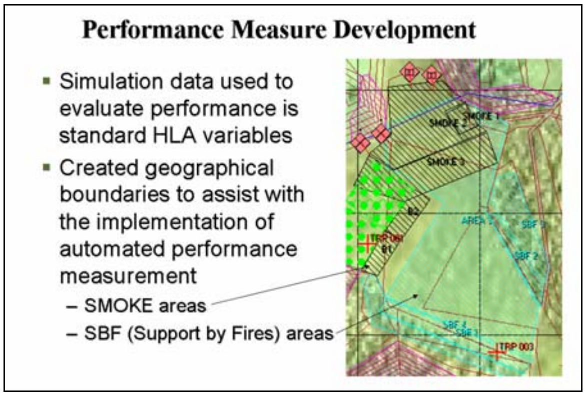

Figure 9. Geographical Boundaries for Metrics

We are developing rules to increase/decrease scores of implicated enabling learning objectives (ELOs). Optimal action will increase associated ELO score(s), while less than optimal action or common error will decrease associated ELO score(s). The simulation data required to evaluate these performance measures are primarily HLA variables. Additionally, we have created geographical boundaries to assist with the implementation of automated performance measurement (Figure 9). Figure 10 provides an example of the performance measures being developed.

Future Prototype Implementation Plans

We are currently in the process of implementing prototype and are just starting to implement the components that will:

- Publish *MAGTF XXI* HLA data for metric evaluation,
- Calculate the pre-defined metrics for the expected student actions, and
- Update the scores of the ELOs associated with the metrics evaluated.

- Task: Select optimal support by fire (SBF) location
- Optimal behavior: One tank in SBF 1 and the other tank in SBF 2
- Common error: Move into less optimal areas – implicate:
  - ELO1.1 Interpret contour lines
  - ELO1.2 Interpret symbology for vegetation.
  - ELO1.3 Interpret symbology for inaccessible areas.
  - ELO2.1 Indicate use of terrain analysis tool
  - ELO2.2 Indicate use of the multi-point move
  - ELO2.3 Indicate route following on multipoint move
  - ELO4.1 Indicate selection of suppress by fire locations

Figure 10. Example Metric Specification

Our development plan calls for an iterative development and testing process. Specifically, we will conduct a pilot test that will involve having participants perform the scenarios so that the scoring logic applied to the ELOs can be evaluated and adjusted as necessary to accurately reflect mastery of the various ELOs. Additionally, we are currently developing the logic that will allow for the selection of scenarios that best address the ELOs that have been implicated. The scheduled completion of the prototype is October 2006. Future efforts are being planned to conduct a training effectiveness evaluation to study the impact on time to mastery and level of learning performance provided by the Performance-Based Advancement method.

SUMMARY

The ADL Initiative is moving forward with the development of methods and standards to provide tailored training that is accessible anytime, anywhere. Initially, the ADL Initiative focused on the implementation of distributed instructional technologies to meet individual learning objectives. As the ADL Initiative has progressed and implemented standards, in particular, SCORM 2004, it is looking to extend these methods to support simulation-based training for individual, and eventually, team/collective training needs.

Scenario-based simulations provide a rich environment for training complex tasks. Additionally, simulation-based training environments provide the student with the ability to perform a task without the constraints of pre-defined actions/answers. However, this lack of constraint makes the evaluation of student performance challenging as student behaviors can be interpreted in several ways. To address this challenge, the Performance-Based Advancement method was developed and is currently being evaluated through the development of a prototype. The prototype will allow for training effectiveness evaluation of this method to assess its impact on reducing length of training and its instructional benefits.

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