Supplementing Classroom Training with a Distributed Refresher Intelligent Tutoring System

Randy Jensen
Richard Stottler
Stottler Henke Associates, Inc.
San Mateo, CA
Jensen@StottlerHenke.com
Stottler@StottlerHenke.com

Dr. Sharon Garcia
Air Force Research Laboratory
Brooks AFB, TX
Sharon.Garcia@Brooks.af.mil

Milton Waddell
Air Force Command & Control Warrior School
Hurlburt Field, FL
Milton.Waddell@Hurlburt.af.mil

ABSTRACT

The training regimen for personnel entering an Aerospace Operations Center (AOC) must cover a complex organizational structure with complex information flows, both horizontally and vertically. Training and orientation includes classroom lectures on many different specialty areas within the AOC, supplemented with exercises offering limited practice in greater depth with some of these areas. Recent exercises have revealed a need for further refresher training, particularly in focus areas within the AOC that involve complex decision-making based on AOC-specific processes, as opposed to general operational knowledge or experience. This paper presents a proof-of-concept system developed to demonstrate web-based refresher training for the Master Air Attack Plan (MAAP) focus area within the AOC. The benefits of refresher training are well-documented, for the flexibility they provide trainees in reviewing concepts on their own from different locations and "just-in-time" when given a new assignment. However, distributed refresher training without an intelligent tutoring component can amount to little more than an online textbook. By implementing Intelligent Tutoring System (ITS) methods in the distributed setting, trainees can benefit from scenario-specific and student-specific feedback in response to their performance on simulated operational exercises. The system described in this paper is based on a limited principle hierarchy developed and integrated with an online simulation. This simulation models an existing software environment for the MAAP decision-making process. The student is given an introductory briefing on a targeting and resource allocation task, and the student's subsequent performance in developing an attack plan and information coordination plan is evaluated in terms of the system's principle hierarchy. The system supports an iterative training loop, where the student can revisit the exercise to modify earlier planning decisions, and receive updated feedback.

ABOUT THE AUTHORS

Randy Jensen is a Project Manager for Stottler Henke Associates, Inc. and has developed intelligent tutoring systems and prototypes for a variety of domains, including a current project for training mission rehearsal with control of distributed robotic vehicles for Future Combat Systems concept trainers.

Dr. Sharon K. Garcia has been a research psychologist with the Air Force Research Laboratory for 23 years, conducting research in manpower, personnel, and training. Her primary area of expertise has been in the area of computer-based cognitive and non-cognitive skills training for various Air Force domains. She is responsible for managing research in computer-based training (CBT) and intelligent systems environments. She received her Ph.D. from St. Mary's University in counseling psychology, and holds a M.A. in experimental psychology.

Milton Waddell is a researcher and instructor for Air Force Command and Control Warrior School. He teaches and develops numerous lessons for the air tasking order (ATO), strategy development, target development, master air attack planning, and force execution. He is a retired Air Force officer and has flown numerous aircraft.

Richard Stottler co-founded Stottler Henke Associates, Inc., an artificial intelligence consulting firm in San Mateo, California in 1988. He has been principal investigator on a number of tactical decision-making intelligent tutoring system projects and is working on an ITS prototype for the future combat system.

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INTRODUCTION

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The benefits of refresher training are well-documented, for the flexibility they provide trainees in reviewing concepts on their own from different locations and "just-in-time" when given a new assignment. However, distributed refresher training without an intelligent tutoring component can amount to little more than an online textbook. By implementing Intelligent Tutoring System (ITS) methods in the distributed setting, trainees can benefit from scenario-specific and student-specific feedback in response to their performance on simulated operational exercises.

The system described in this paper is based on a limited principle hierarchy, which was developed and integrated with an online simulation. This simulation models an existing software environment for the MAAP decision-making process. The student is given an introductory briefing on a targeting and resource allocation task, and the student's subsequent performance in developing an attack plan and information coordination plan is evaluated in terms of the system's principle hierarchy. The system supports an iterative training loop, where the student can revisit the exercise to modify earlier planning decisions, and receive updated feedback.

AOC TRAINING REQUIREMENTS

The Air Force Command and Control Training and Innovation Group is responsible for providing training for Aerospace Operations Center (AOC) operational personnel. However, the AOC is very complex, with complex processes, complex information flows (both horizontal and vertical), and dozens of personnel. The current training regimen consists of instructor-led courses combined with practice in independent sessions where students gain specific practice with examples. Each trainee must understand the overall structures and process of the AOC; how their specific role fits into both of these; how to assess the importance and route incoming information in the context of these information flows, organizational structures, and current high-level and lower level goals and objectives. In addition, they must understand the principles behind and how to use the application software and systems and how to correctly apply all of this knowledge to make correct decisions in operational situations. These decisions may include both decisions relating to information flow or application use as well as decisions relating to a particular area of expertise, such as defensive tactics or logistics.

The Joint Aerospace Command and Control Course (JAC2C) currently given at the C2 Warrior School includes many sections with overview level orientation in many different specialty areas within the AOC. Classroom lectures are supplemented with exercises offering limited practice in greater depth with some of these areas. The instructor-led training is an essential introduction to the AOC, its processes, and information flow within the AOC. But recent BLUEFLAG exercises have revealed a need for further refresher training, particularly in focus areas within the AOC that involve complex decision-making based on AOC-specific processes, as opposed to general operational knowledge or experience. In particular, the Master Air Attack Plan (MAAP) process within the AOC Combat Plans division has been an area targeted for supplemental tools and training, due to both the complexity and criticality of the MAAP process, and also the need for students to develop effective cognitive models for how to use information effectively while preparing a MAAP.

There are many examples in the MAAP process where competing principles must be resolved in the process of allocating resources to targets. If there are two groups of targets, one near and one far with respect to an available base, and the near group has mostly low priority targets and the far group has high priority targets, then the planner needs to be flexible in the application of heuristics for target allocation. It is appropriate to consider other issues as well that may resolve such a dilemma. For example, would a strike package planned for the far target group encounter any known surface-air missile (SAM) sites along the flight path? Perhaps those SAMs should be addressed first in a preliminary wave before dealing with the far targets. Are there any high priority targets in other nearby target groups that could be combined in a package that strikes the near group? What is the nature of the desired effect for the far targets? If successive strikes will be depending on the achievement of the objectives associated with the far targets, then the high priority level associated with these targets may outweigh the additional difficulty or risk in reaching them. For each of these different factors, the student must not only be able to consider how they should impact a planning decision, but also know to ask these questions and know how to find the answers.

The MAAP Toolkit is a software suite recently developed to accelerate MAAP build time, simplify the revision process, reduce the number of required personnel, and integrate different data sources. These are all critical benefits, and have all been quantified at JEFX trials; for example, a 30% reduction in MAAP production time was measured. Therefore, while this tool provides an important value for facilitating the process, instructors still noted a deficiency in trainees when it came to their cognitive models of the MAAP process itself, and a lack of understanding of key concepts involved in best practice decision-making for optimizing a Master Air Attack Plan. Deficiencies range from overlooking regular planning considerations like allocating critical support assets such as refueling nodes or suppression of enemy air defense (SEAD) with the construction of a strike package, to over-tasking strike assets, or failing to consider new information from Intelligence Surveillance and Reconnaissance (ISR), or the Battlefield Coordination Detachment (BCD). Thus, the current training regimen for students headed for service in a MAAP team needs to be augmented with refresher training specifically focusing on the MAAP process, so that students can get more practice and feedback with exercises. They need to gain familiarity not only with the operational concepts, but also with the structure of the MAAP team and the inputs, outputs, and process in which the operational concepts are best applied.

DETERMINING THE COMPLEMENTARY ROLES FOR CLASSROOM AND DISTRIBUTED REFRESHER TRAINING

Because the current training for the MAAP process occurs within the context of a broad overview perspective, there is a clearly identifiable need for more specific practice and feedback-oriented training. Current instructors and program managers alike agreed that refresher training would complement the existing training effectively, especially if delivered as a distributed trainer, by providing the opportunity for more in-depth practice with MAAP exercises, but with more flexible time requirements and virtually no additional facility requirements. With the opportunity for more practice in operational exercises, students can develop better cognitive models of the MAAP process, which leads to better decision-making. Although the refresher trainer will have several key distinctions from the existing broad classroom-based curriculum, it can also leverage much of the existing embedded knowledge and courseware. Reusable materials include the Pacifica conflict scenario, sample inputs used for classroom-based exercises, such as JIPTLs (Joint Integrated Prioritized Target Lists), resource lists, realistic force availability breakdowns, weapons/loads guides, weather reports, and so forth. In addition, the instructors themselves represent a valuable asset for constructing both the exercises for the system and the evaluation criteria for assessing student outputs.

With the objective of providing refresher training as opposed to initial training, the system employs simplified exercises to target specific principles. This is most suitable to the distributed refresher training setting, which is generally most effective as a platform for repetitive practice with numerous exercises of shorter duration (1 hour or less). One of the important benefits of making distributed training available is the flexibility it offers trainees in the sense of providing the opportunity for access from different locations, and for different durations of time. So a critical difference from classroom training when it comes to instructional authoring is the specific requirement that refresher training exercises be designed for compatibility with this kind of usage profile, which means shorter duration. In order to accomplish this, each exercise needs to abstract certain concepts. This is necessary to enable students to focus on key concepts and that they can then be evaluated on accordingly. Although the operational exercises for the refresher ITS are designed for abstraction and brevity, there are no intrinsic technical obstacles to exercises of longer duration, so future systems may include a minority of such exercises, depending on instructor input on what is appropriate.

MODELING THE DECISION-MAKING ENVIRONMENT AND PRINCIPLES

With the MAAP process domain, there are different kinds of skills and knowledge that need to be applied. One skill type relates to decision-making concepts involved in planning; for example, grouping targets by geography and priority, and resolving resource conflicts. Another skill type involves domain-specific knowledge; for example, an A-10 can carry an MK-84 SCL, but an F-15E cannot. It is important to note that much of the second type of domain-specific information is automatically provided within the environment of the MAAP Toolkit. This has two consequences for the refresher trainer. First, it establishes a dividing line for the kinds of concepts that need to be addressed in refresher training. Since the second type of information is readily available from software tools and resource sheets, it was left outside the scope of the instructional concepts to be addressed in the system. Second, it presents an embedded knowledge problem for the refresher ITS. For example, if a student using the ITS attempts to create an F-15E mission carrying an MK-84, either the system should give a warning or simply disallow this action. The consequence of this requirement is that the system needs to maintain a basic database of domain knowledge that can be used on first pass evaluations of student actions. A preliminary rough version of this database is implemented for numerous aircraft and weapons in the proof-of-concept ITS.

The ITS uses exercises based on the Pacifica scenario, which is also used for training in other military applications and courses. It has been observed in Air Force training that students respond best to training scenarios that can be briefed in detail to provide an element of reality, which essentially establishes a sense of "what they are fighting for." The Pacifica scenario is commonly used because students are often already familiar with the broad parameters of the conflict, and instructors can make use of this familiarity in the introductory briefing that establishes the setup for a particular exercise. Likewise in the distributed setting, by using the Pacifica scenario, the spinup time for each exercise provided by the ITS can be minimized, and students can get to the exercises quickly. The exercise scenario in the proof-of-concept system was designed with the input of instructors at the C2 Warrior School who have developed similar examples for classroom instruction and practice.

Broadly speaking, the inputs to the student in the ITS consist of a geographic map, a merged collection of resource sheets, and a target list. The student's output is a simplified version of a Master Air Attack Plan - essentially a list of missions and packages developed for the day's ATO. The student constructs a solution in the web-based simulation environment, which is a simplified version of the operational MAAP Toolkit environment. Although the ITS is not a primary visible component of the user interface, in contrast with the simulation environment, the automated evaluation it performs on student outputs is a major part of the software functionality in this system. Once the student has completed the preparation of the outputs for a given operational exercise, the ITS evaluation is triggered with a simple single button.

The ITS employs a target list acting as a simulated JIPTL, which in the real AOC comes to the MAAP team from the Guidance Apportionment and Targeting (GAT) team, but was developed for this proof-of-concept by instructors from the C2 Warrior School at Hurlburt Field. In the simulation interface, the student can create either strike or support missions. In the operational exercises, the majority of the student actions involve specifying strike missions, allocating necessary support, and resolving resource conflicts associated with this part of the planning process. An example instructional principle is to understand when and how to allocate Air Refueling for missions in part of a strike package. For all the principles in the hierarchy, the student actions in the simulation environment are monitored so that customized feedback can be provided.

AUTOMATED EVALUATION, FEEDBACK, AND REMEDIATION THROUGH OPERATIONAL EXERCISE

The ITS is structured around an operational exercise format which includes a set of preliminary briefings to establish the broad scenario, the specific target, the tactical objectives and commander's intent, and any relevant intelligence reports.

Figure 1: Target Briefing Screen

Figure 1 shows the Target Briefing for the Bishop Airfield scenario. These briefings do not only establish context for the planning task, they also provide essential information that should be taken into account in the MAAP that the student will develop. For example, the briefings provide information about known enemy SAM sites, which the student must address in the MAAP, typically with some form of air suppression.

Once the student is ready to begin the air attack planning process, the next step is to enter a MAAP Workspace tab in the web-based environment. The workspace is the setting for the entry of all strike and support missions.

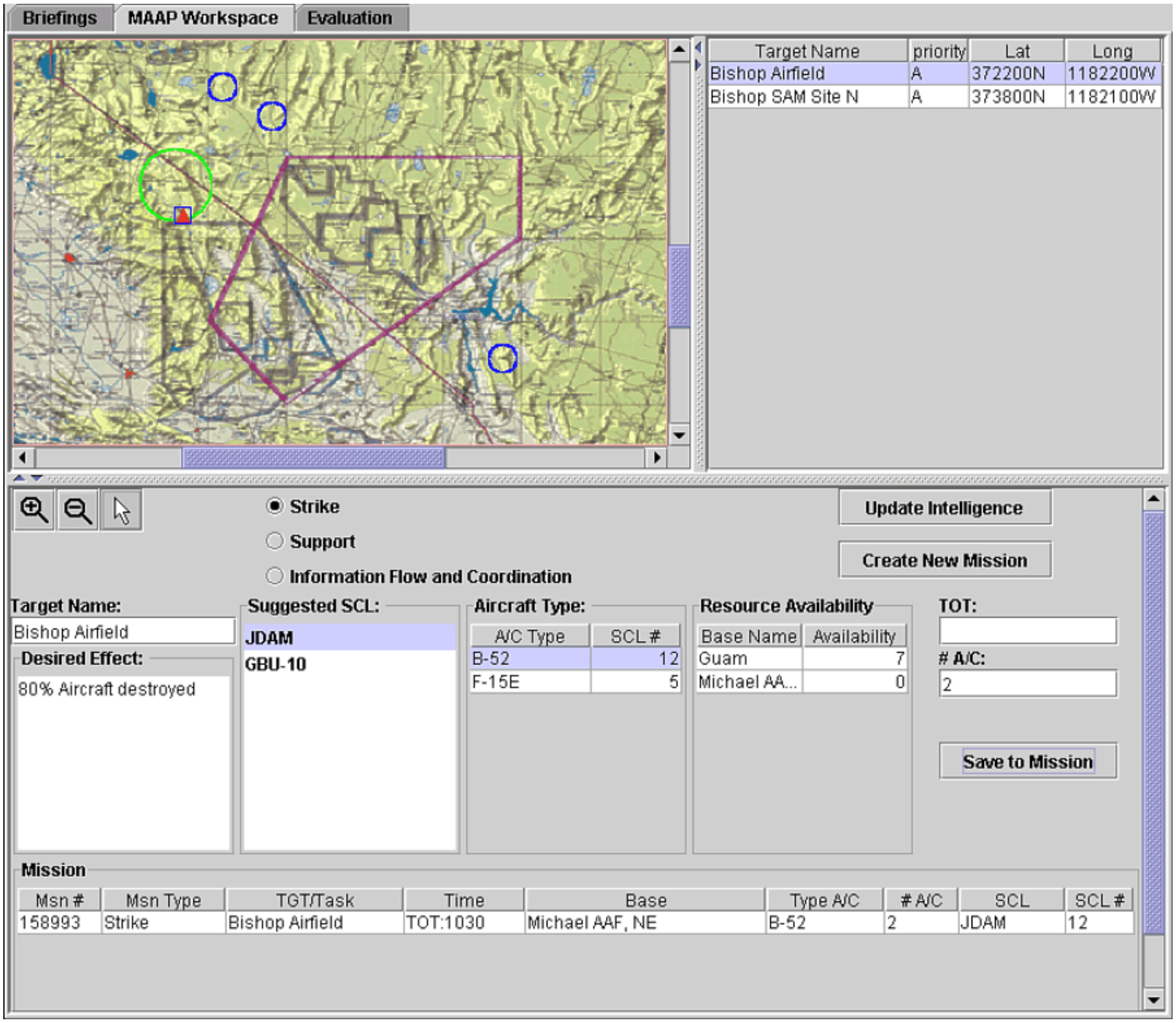

Figure 2: Strike Planning Interface

For a strike mission, the student can select a target either visually on a geographical map or textually from a target list table. The student can zoom in or out on the map image, with targets maintaining their relative positions. When the student selects a target on the map, the corresponding row in the target list is highlighted, and likewise in the opposite sequence. With a target selected, the student can choose individual DMPIs (Desired Mean Points of Impact) associated with the target, and see the desired effect for each, as would normally be provided by GAT on a target nomination list. For each DMPI, there is a list of suggested SCLs (Standard Conventional Loads), again based on GAT input, from which the student can make the decision about assigning resources and weapons for the current DMPI. This decision is based on knowledge about available resources in terms of aircraft, and the locations of the bases or assets from which the aircraft originates. A limited resource sheet database is implemented with the system, so that when the student selects a potential SCL from which to construct a mission, only the suitable and available aircraft appear in the Aircraft Type list. Similarly, for each aircraft in this list, only the bases that have the selected aircraft will appear in the Resource Availability list. Once a DMPI, SCL, Aircraft, and Resource are selected, the student may specify a TOT (Time On Target) and create a strike mission with these parameters. The mission is added to the Missions list at the bottom of the environment, and will ultimately be evaluated by the ITS as part of the student's output.

The process is somewhat different for support missions, as they can involve a variety of support tasks, such as escort, refueling, or Suppression of Enemy Air Defense (SEAD), which may not be associated with specific DMPIs or weapons. These missions are specified in a separate environment that pops up upon selection of the Support Task button, and they are subsequently added to the student's list of outputs for evaluation.

Additionally, there is a third category of student output, which involves the explicit designation of information coordination plans. The student is provided a checklist for designating coordination with liaison elements from other forces and with other sources of data such as collection management.

Once the student has completed preparing the outputs for a given operational exercise, the ITS evaluation and debriefing is triggered by clicking on the Evaluate button.

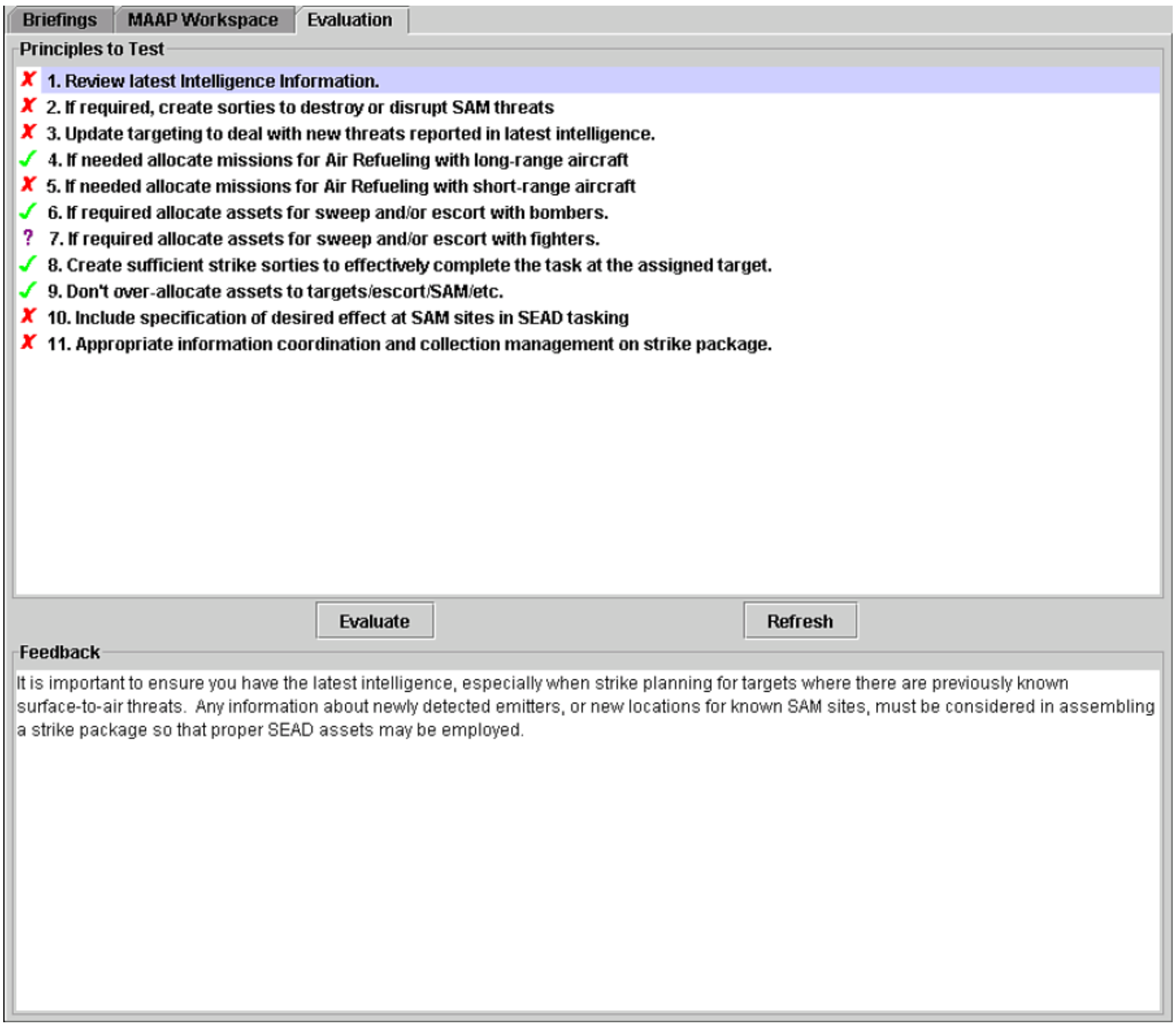

Figure 3: ITS Feedback Screen

Figure 3 shows the feedback screen provided by the ITS after the student has assembled a MAAP and requested initial evaluation. A simple report card format is provided, with a summary of the relevant decision making principles, annotated to reflect the student's success or failure with each. Successfully understood principles are marked with a green checkmark, and failed principles are marked with a red X. In some cases, there may be additional information related to a principle, which is constructive to report to the student, without necessarily returning a pass or fail judgment, in which case the principle is marked with a question mark. The student can receive more details by clicking on an individual principle and reading the information provided in the Feedback region. The ITS is designed around an iterative model, where students can update their air attack plans based on the feedback received, and return successive times for additional evaluation. The feedback provided by the ITS intentionally avoids giving specific solutions, as opposed to general suggestions about key issues for the student to consider.

For each operational exercise, the student outputs are evaluated with respect to a collection of fragmentary good and bad answers that have been developed with the input of instructors. In a simple example, the student may have forgotten to allocate missions for Air Refueling for one or more of the aircraft included in the strike package. In a more complicated example, a student may have allocated weapons for a DMPI as part of a given strike package that meet the GAT recommendations and correct prioritization order. This would match with the corresponding elements of a good solution provided by instructors for the ITS. However, suppose the student used assets from a base that is distant from the specified targets, when aircraft from another base closer to the target could have been used with the same weapons. This could be especially bad if the longer flight path increased exposure to surface-air missiles or other threats, or required unnecessary use of refueling nodes as a result. This would match with another fragmentary bad solution, and trigger system feedback accordingly. Thus, in the debriefing, the student receives an appropriate combination of positive and negative feedback, which directly responds to performance in the exercise.

The ITS is completely web-based, and can be viewed over a browser on Java-enabled machines. The architecture primarily involves an interface applet which communicates with a server-side database and ITS. The server-side database includes the domain-related information such as resource compatibility (for example, which aircraft can carry which loads), the data for the operational exercises (target lists, resource availability), a small amount of courseware, information about the student which is maintained in a student model, and a principle hierarchy based on the cognitive model of the domain and the small set of principles selected for treatment in the system. The ITS also resides on the server, initially triggered by a message from the applet and then after completing a review of student outputs, it provides a debriefing back to the applet's browser interface. The proof-of-concept system serves to demonstrate a browser-based environment where domain-specific knowledge can be embedded to simulate the many data sources that serve as inputs to the MAAP process, which is a traditional information flow problem within the AOC.

LESSONS LEARNED AND FUTURE APPLICATIONS

As a proof-of-concept, this system was developed with the intention of demonstrating that meaningful instructional value can be realized in the distributed refresher setting, when coupled with ITS technology. Although there is an abstraction process involved in presenting complex problems in a web-based platform, it is clearly possible to isolate key instructional principles in a practice environment and provide individualized performance feedback on these principles. The research effort also extended into design work for a more full-scale refresher ITS for the AOC domain, much of which consisted of developing more detailed specifications for components of the proof-of-concept system.

In order to tailor the course of study to the individual student, the ITS keeps a model of each student who uses the ITS. The student model contains the student's actions and decisions during different scenario exercises, the principles, models, processes, skills, procedures, and techniques, which have been presented, and those that have been mastered based on performance in exercises. The set of principles, models, processes, procedures, factors, and strategies referenced in the solutions of problems the student has solved successfully represent the student's acquired skills. Based on the pattern of unsatisfactory performance on exercises, a set of topics, principles, or combinations of them, can be developed which form a hypothesis as to what information the student does not understand. For example, the student might not understand the MAAP principle, "Include electronic warfare measures as needed in attack packages." Based on this hypothesis and the exercises solved incorrectly, similar examples can be shown to increase the student's understanding. For example, given the previous MAAP principle in which the student is deficient, the ITS might present an exercise where the enemy has radar nodes that should be jammed with electronic countermeasures as part of a strike package. It may be appropriate to require the student to re-experience some of the course topic material as well, perhaps to a greater level of detail. Based on this hypothesis, a new set of exercises can be generated for testing the success of the remediation. A course instructor or manager to monitor the student's progress through topics and performance in exercises can also reference the student model. The student model will reflect the skills, knowledge, and error-rate of the student. The student model evolves in size and complexity as the skills and knowledge of the student increase.

After re-testing, the success of the remedial instruction can be gauged. By varying the type of this remedial instruction, the most appropriate instructional technique for this student can be inferred. Furthermore, the ITS can infer different “best” instructional techniques for different types of principles and can thus infer different best instructional approaches for different types of tasks.

The system design takes a very general view of what is meant by the term “Principle.” It is basically anything which must be understood and applied during cognitive decision-making. In the case of AOC operations, individual principles might represent that the student understands the importance of various types of information from different groups. For example, one particular principle might represent that a student understands that the attack package to be prepared in an exercise is a part of a large push, and thus the strikes’ TOTs should match up with the guidance from the strategy cell with regard to serial or parallel attacks. This is a specific component of an information flow model. However, an AOC individual must also understand how to make tradeoffs and deconfliction within the collection of targets in the individual’s own package command, and this would be represented and assessed by several individual principles. Thus very different types of knowledge can be represented in the ITS and tracked.

The evaluation component of the system design is one of the most complex. In traditional ITSs, an expert system is applied to the same problem as the student, and their actions are compared. Unfortunately, the creation of the expert system is difficult or impossible even for a skilled knowledge engineer in most military domains. In our approach, the correct actions (or an exercise-specific way to derive them) are stored with the exercise, so the Evaluate module need only compare the student’s actions to these.

One refinement of this method is to store correct and common incorrect scenario fragments entered by the instructor for each exercise. Each component of the fragment is annotated with an explanation as to why that solution is correct, partially correct, or wrong along with the principle mastery (good or bad) that is indicated by the trainee’s decision if it matches that component of the fragment. After the trainee enters a solution, it is compared to each of the fragments and the closest matching ones are used as a basis for assembling the debriefing and the list of principles mastered, as illustrated by the student’s solution. For illustration, consider a simple exercise with two target groupings J and K. The J targets are all B priority, and the K grouping includes mostly A priority targets. Suppose further that the GAT recommendations list GBU-12s as the best choice weapons for both sets of targets, but that only one aircraft capable of delivering GBU-12s is available for this wave within this package. If the student allocates the aircraft and the GBU-12s to the J targets, then this qualifies as passing the principle associated with using the most recommended weapon for that particular target set. However, the student also fails the principle of allocating available assets first for the highest priority targets. Triggering the different pass and fail principles depends on the representation of solution fragments for the operational exercise so that the system can perform matching during the evaluation process. Authoring the Evaluation Knowledge simply requires entering these annotated exercise solution fragments.

Many of the task areas within the AOC could make use of the instructional tools described here with little transition cost. The design and implementation work in this system represents a preliminary step for future implementation of more comprehensive refresher training, both for the MAAP process and for other areas within the AOC.

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