INFORMATION TECHNOLOGY ADVANCES WILL SUPPORT ADVANCED DISTRIBUTED LEARNING ANYTIME AND ANYWHERE

John J. Morris
Sonalysts, Inc.
Waterford, CT 06385

Janet M. Weisenford
Naval Air Warfare Center Training Systems Division
Orlando, FL 32826

Wiley N. Boland, Jr. Ed.D.
Asymetrix Learning Systems, Inc.
Virginia Beach, VA 23545

ABSTRACT

Information technology advances will support advanced distributed learning anytime and anywhere. However, similar advances in learning technologies are required to achieve cost-effective readiness and enhanced job performance. Adaptive learning that accommodates mastery differences in individual learners also offers benefits of high media reuse for continuum training - initial, refresher, remedial, and just-in-time instruction and performance aiding. High media reuse also can accrue from multiple courses supporting curricula related by personnel, equipment, or domain/core skills.

The Office of Naval Research (ONR) sponsored a Dual-Use Applications Program (DUAP) through the Naval Air Warfare Center Training Systems Division (NAWCTSD) to further “Artificially Intelligent Tutoring for Advanced Distributed Learning.” A competitive procurement resulted in a technical investment agreement with Asymetrix Learning Systems, Inc. and Sonalysts, Inc. to enhance existing technologies and commercialize the resulting product(s).

The technical approach creates and delivers an individualized education plan at run-time. The first level of adaptivity determines “what to teach” by selecting and ordering the presentation of topics (that correspond to learning objectives). Topics are selected based on course definition data consisting of instructional groupings (course, module, lesson, etc.), instruction and testing strategy, and prerequisites, as well as current learner mastery. The second level of adaptivity determines “how to teach” by selecting specific learning objects (that support specific objectives/topics) based on student characteristics, mastery, and instructional history. Learning objects are data files consisting of one or more frames and associated media references that are attributed with objective/topic, detail level, score-based criterion, learner population.

After reviewing instructional issues, the paper also addresses the mechanisms, processes, and lessons learned from the DUAP technical investment agreement including Government goals and objectives. In addition to user-community involvement and program management from NAWCTSD, representatives from the

Office of the Secretary of Defense, and Defense Acquisition University participated in working groups to evaluate progress and interim products, and to consider changes in instructional design processes to exploit adaptive learning capabilities.

The paper concludes with the implications for linking of adaptive learning capabilities to simulation-based tutors, embedded performance support, and learning management systems. Specifically, the learner model architecture is compatible with several simulation-based tutors, objective-based scenario generation, and training evaluation tools that have been developed under NAWCTSD training research programs.

ABOUT THE AUTHORS

Mr. John J. Morris is an Executive Vice President of Sonalysts, Inc. of Sonalysts, Inc., Waterford, CT. He has a Bachelor's Degree from the University of Michigan, a Master of Business Administration Degree from the University of Rhode Island, and more than 26 years of active and reserve naval service in Surface Warfare and Intelligence, respectively. Relevant civilian experience includes 22 years with Sonalysts in naval operations research, training, and advanced training technology development including training requirements analysis, simulation-based trainers, interactive multimedia instruction, intelligent tutoring systems, and embedded training applications development. He is Sonalysts program manager for the DUAP "Artificially Intelligent Tutoring for Advanced Distributed Learning" efforts.

Ms. Janet M. Weisenford is the Program Manager for Advanced Distributed Learning at the Naval Air Warfare Center Training Systems Division. She has a Bachelor’s Degree from New College and a Master’s Degree In Public and International Affairs from the University of Pittsburgh. She has more than 20 years of public service, working at all levels of the Department of Defense, including the Office of the Secretary of Defense. She is the Navy Project Manager for the DUAP "Artificially Intelligent Tutoring for Advanced Distributed Learning" efforts.

Dr. Wiley N. Boland, Jr. is the Federal Sales Business Development Manager for Asymetrix Learning Systems, Inc., Bellevue, WA. He has more than 28 years of experience in instructional products development focusing on guiding learners to goals and skills mastery. He is an instructional systems designer with broad experience and background. Dr. Boland specializes in interactive multimedia courseware and electronically delivered training programs. A Marine aviator currently on the retired list, he holds an educational doctorate from Virginia Tech.

INTRODUCTION

Information technology advances will support advanced distributed learning anytime and anywhere. However, similar advances in learning technologies are required to achieve cost-effective readiness and enhanced job performance. Much of the focus of advanced learning technologies has been devoted to definition (and desired standardization) of learning objects that can be shared and reused to further reduce costs and improve effectiveness interactive multimedia instruction (IMI).

Several different groups have tackled the definitions of learning objects, as well as associated issues of metadata tagging, delivery mechanisms, and the like. The purpose of this paper is to present a Government and industry effort that would enhance and commercialize IMI authoring and delivery environments to support adaptive learning.

Adaptive learning in this paper refers to the capability to automatically create and deliver an “individualized education plan” at run time based on a learner’s mastery of defined learning objectives, available shareable content objects (SCOs) that support learning objectives, and course/ instructional definition data.

The premise of adaptive learning is that IMI (including computer-aided instruction (CAI) and computer-based training (CBT) offers potential cost savings in courseware development and instructional efficiencies. More importantly, adaptive learning that accommodates mastery differences in individual learners also has the potential to improve training effectiveness depending on the quantity, quality, and diversity of learning activities available. When coupled with embedded training and simulation-based intelligent tutors, adaptive learning brings the vision of performance-based embedded support and training management closer to reality.

BACKGROUND

The constant struggle for buyers, designers, developers, and implementers of IMI is to achieve the best return on investment (ROI) for training systems. The drastic reductions in overall military spending forced concomitant reductions in fixed training infrastructure, instructor billets, training travel allowances, and training provided.

However, the need for better and cheaper training is not unique to the military. All levels of Government, commerce, industry, and educational institutions struggle to keep pace with our increasingly information rich and competitive world.

Fortunately, information technology advances in personal computers, communications, and software productivity tools have contributed to the state-of-the-art in authoring and delivery of IMI. We also have seen concomitant improvements in modeling and simulation-based training systems and collaborative distance learning, but these are not the focus of this paper.

Acknowledging the dangers of oversimplification, much of the IMI programs that have been developed over the last few years have sought to replace or augment traditional classroom instruction. The combinations of economics in education and training infrastructure and advances in electronic delivery have pushed learning to the field, ship, and home, but the classroom and lesson paradigm remains.

Advances in technology also stir other visions, even heresy, such as "Why should we train anyway?" "Aren't we really interested in job performance, mission readiness, or baseline competency?" -- "Who cares whether an individual completes a course of instruction; is she/he qualified for job tasks?"

The benefits of intelligent computer-assisted instruction (ICAI) have been surveyed in several reports (See reference (1)). And there are many examples of artificially intelligent tutors that have been applied to a variety of domains. However, most intelligent tutors have been spawned as research and development efforts or applied to critical training problems where ROI was favorable to traditional training approaches. For example, the AN/SPY-1 Radar System Controller Intelligent Training Aid (RSC ITA) that is in use at the Aegis Training and Readiness Center avoided procurement of a second set of radar technical training equipment (TTE). The RSC ITA tutor component supported complex operations practice with a 12:1 student to instructor ratio (See reference (2)).

The challenge remains to accrue the benefits of intelligent tutoring and adaptive learning to mainstream education and training programs. The ONR sponsored a fiscal year 99/00 DUAP topic through NAWCTSD to further "Artificially Intelligent Tutoring for Advanced Distributed Learning." A competitive procurement resulted in a technical investment agreement with Asymetrix Learning Systems, Inc. and Sonalysts, Inc. to enhance existing technologies and commercialize the resulting product(s). While much of the program addresses advanced distributed learning enhancements, this paper focuses on the authoring and delivery of adaptive IMI.

TECHNICAL APPROACH

The characteristics of current commercial-off-the-shelf (COTS) IMI authoring and delivery products are illustrated in figure 1. The specifics of the instructional hierarchy and functional allocation among delivery and training management system products may differ. However, generally the training path or navigation through a course of instruction, lesson, or topic is specified at the time of design and programmed or authored during development.

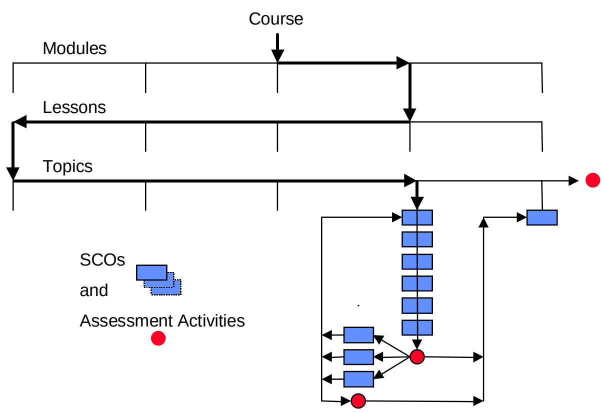

Figure 1. Conventional Interactive Multimedia Instruction Course Structure

Learners proceed through the training program with a fixed level of interactivity that is directly, though non-linearly, proportional to the cost of design and authoring. Figure 1 also depicts our interpretation of an SCO as an instructional template (single or multiframe) and associated media content. Assessment activities are typically (but not limited to) two-state, multiple choice, or hot-spot questions. Navigation through the instructional program is based on pre-programmed response to each learner action.

The current technical approach for adaptive learning is based on Sonalysts InTrain™ domain-independent intelligent tutoring technology that has been fielded in numerous training courses and advanced technology demonstrations since 1994. Under the current technical investment agreement, Sonalysts has developed authoring tools and will integrate with Asymetrix ToolBook™ products.

The InTrain approach differs from conventional IMI approaches in that there is no pre-defined instructional delivery plan. Learning objectives are defined by the instructional designer within a learner model structure to the level of granularity desired. The learner model also contains other learner identification and characteristics. As learners are enrolled into a training program, learning objectives are assigned. As learners interact with instructional or assessment activities, InTrain maintains each student's current mastery data, complete instructional history, as well as traditional curriculum-based data as test scores and course/modules/lessons are completed.

InTrain exploits links between learning objectives and SCO groups and assessment activities as illustrated in Figure 2.

InTrain instructional planning capabilities support two levels of learning adaptivity that is implemented as an individualized education plan at run-time. The first level of adaptivity determines "what to teach" by selecting and ordering the presentation of SCO groups (that correspond to learning objectives). SCO groups are selected based on course definition data consisting of instructional groupings (course, module, lesson, etc.), instruction and testing strategy, and prerequisites, as well as current learner mastery.

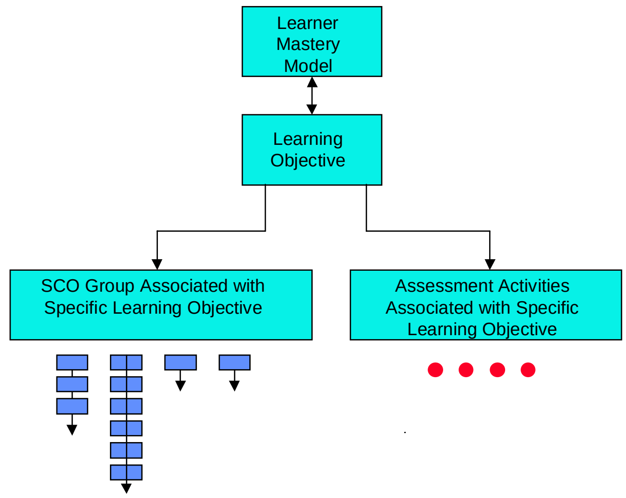

Figure 2. Adaptive Learning Concept

The second level of adaptivity determines "how to teach" by selecting specific SCOs (that support specific objectives/topics) based on student characteristics, mastery, and instructional history. SCOs are data files consisting of one or more frames and associated media references that are attributed with information such as objective/topic, detail level, score-based criterion, learner population.

Figure 3 illustrates an overall instructional process for the adaptive learning approach. Generally, a learner logs on to the enterprise learning management system (for example, Librarian™) and initiates the program of instruction that has been assigned to him/her.

Where the individual learner begins is defined by course definitional data that is authored during design for such items as

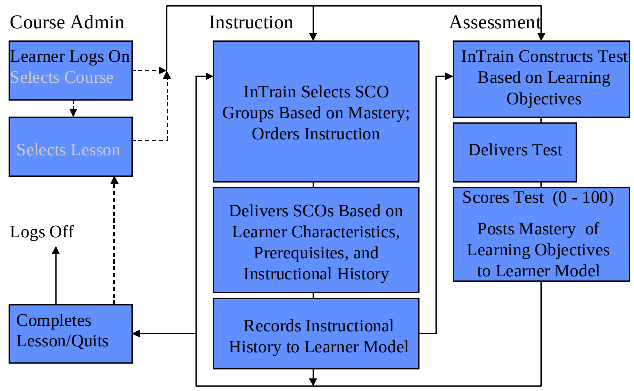

Figure 3. Adaptive Learning Process

- Instructional granularity (course, module, lesson, topic, etc.)
- Sequencing instructional approach
  - Initial training (instruct, assess, instruct, assess)
  - Refresher training (assess, instruct, assess)
  - Performance aiding (instruct)
- Mastery pre-requisites
- Degree of learner control

Course definitional data allows instructional designers to create a continuum of training programs using push strategies (initial and refresher training) as well as pull strategies (just-in-time, remedial instruction, and performance support) using the same SCOs.

The first level of adaptivity supports efficiency of instruction for refresher training, just-in-time training, or performance support. The robustness of the learning experience in terms of ability to adapt to individual learner capabilities and preferences is dependent on the number and diversity of learning activities/ SCOs available.

The adaptive learning authoring tools that have been developed under the DUAP project are quite simple. They provide a graphical user interface that

- Enables adding, deleting, and modifying a learning objective hierarchy to an arbitrary level
- Selects or creates SCOs and assessment activities that support learning objectives
- Associates attributes with SCOs
- Associates SCOs and assessment activities to learning objectives
- Defines course organization (unit, module, lesson, etc.)
- Specifies instructional sequencing strategies
  - Initial training, refresher, etc.
  - Ordering approach
  - Mastery prerequisites

The conceptual architecture for an adaptive learning system is illustrated in figure 4.

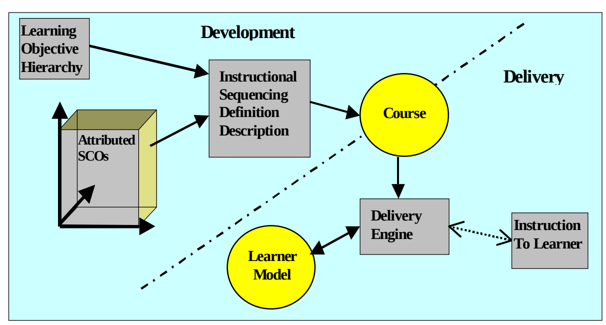

Figure 4. Adaptive Learning Development and Delivery Environments

The adaptive learning technology that has been described thus far is straightforward. It is so clear that one wonders – "What is the advantage? We can hardly afford one SCO per learning objective/topics. How can we afford multiple SCOs that are scaled and attributed by level of detail (high, medium, low), population (apprentice, journeyman, master), or other appropriate dimensions?

Given the paradigm of formal training infrastructure, single course focus, and basic knowledge training objectives, the advantages of adaptive learning are difficult to envision. As we contemplate the possibilities of an integrated learning system that focuses on mission readiness, job performance, or educational competencies our vision becomes clearer. The attainment and maintenance of mastery will become more important than the specific learning path that is followed.

USER COMMUNITY INVOLVEMENT/LESSONS LEARNED

This section addresses the mechanisms, processes, and lessons learned from the DUAP technical investment agreement including Government goals and objectives. In addition to user-community involvement and program management from NAWCTSD, representatives from the Office of the Secretary of Defense, the four military services (via the Joint Services Action Group), and the Defense Acquisition University participated in working groups to evaluate progress and interim products, and to consider changes in instructional design processes to exploit adaptive learning capabilities.

The DUAP program is designed to develop technology that has both military and civilian applications. This will lower the costs of technology development for the military as well as the cost of the actual product by taking advantage of cost sharing up front. Subsequent savings will be achieved through efficiencies in economies of scale and the ability to use commercial items. Unlike traditional government programs, the DUAP program uses agreements that are not governed by the Federal Acquisition Regulations. These agreements allow for commercial accounting, commercial billing, flexible intellectual property rights provisions, and joint program management.

The DUAP program requires fifty-fifty cost sharing between the Government and industry. Proposals are evaluated on their commercial viability in addition to their technical merits.

The Artificially Intelligent Tutoring for Advanced Distributed Learning Project was initiated to develop a commercial authoring tool that provided features to support intelligent tutoring. Research has demonstrated the effectiveness of intelligent tutoring. The major barrier to broad application of intelligent tutoring was that no commercial source offered the capability. The primary objective of this Project was to make that capability available commercially and to make it easy to use. Other features desirable in a commercial authoring tool were also identified based on a survey of the products available and the features missing from the existing commercial products. These features were identified in the solicitation for proposals and were incorporated as objectives for the project. These features include:

- Providing basic intelligent tutoring capability
- Building in instructional system design aids
- Enhancing interface to internet/intranet
- Tracking and updating media assets
- Providing question bank and secure, on-line tests

- Interface personnel management and training management systems

During the negotiations of the agreement, the government industry team agreed to adopt the commercial software development process used by Asymetrix as the process used to manage the project. This process has several critical milestones: development of a marketing requirements document that describes the features to be developed in the software; and design specifications that further define those features, beta product, and final release. The Government team reviews and provides comments to the industry partners at each milestone, recognizing that the greatest opportunity for influence is early in the process. The industry partners receive Government financial payments at the completion of each milestone.

The Government team is working with end users to involve them in the evaluation of the documents and as participants in beta product evaluations.

Lessons learned to date include the importance of shaping the agreement and the process used to accommodate both Government and industry requirements. Due to the shared investment and the objective of producing a commercial product that will satisfy both military and civilian requirements, it is important to achieve a balance between each partner's requirements.

RESEARCH PLANS AND POTENTIAL APPLICATIONS

While the focus of Project efforts to date have been on the design, development, and implementation of adaptive learning authoring tools and technical integration, there are several opportunities for prototype applications and training research.

One area of fruitful research involves comparative analysis to evaluate and quantify efficiencies in design, development, and maintenance of conventional IMI and adaptive learning techniques. The Project demonstration will provide a limited analysis of adaptive learning tool efficiencies based on manipulation of adaptive learning courses previously developed. Specifically, this evaluation will investigate the ability to create and modify additional courses based on existing SCOs.

In addition, user-community involvement has identified a number of planned distributed courses that could be developed by independent developers. These third party evaluations will inevitably occur when a complete tool set is provided, at least in Beta form.

The second area of research will demonstrate the potential for closed-loop performance support and training management. In this case, the authors hope to demonstrate the applicability of adaptive instruction by leveraging existing tutors, such as the AN/SPY-1 RSC ITA. In addition, there are several tutors (standalone and embedded) that are under development as part of other training technology research efforts with the U.S. Army, Navy, and Air Force.

CONCLUSION

This paper highlights one area of enhancement of advanced learning methodologies that are required to maximize the effectiveness of advanced distributed learning. The adaptive learning approach that has been implemented provides an infrastructure for two levels of adaptivity. The first level is with the potential for enhanced efficiency in design, development, and maintenance of IMI products, and, more importantly, efficiencies in the management of learning for initial, refresher, remedial, just-in-time, training and performance aiding products. The second level supports delivery of individualized instruction based on mastery, specific learner characteristics, and instructional history.

The paper documents that progress in advanced learning technology is not merely a technical issue but it also involves changes in the way organizations manage training and education. It also documents the institutional processes that may severely limit the benefits that advanced learning technologies can provide.

Also chronicled is one of the new tools available from Government acquisition reform. Dual Use Science and Technologies (DUST) programs will become more prevalent in the future research and development. Partnering relationships that emphasize research, development, implementation, AND commercialization offer enormous benefits to the community, even if the effect is to raise the bar of competition.

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