INTELLIGENT TUTORING SYSTEM FOR TACTICAL AIRCRAFT TRAINING (ITS-AIR): LESSONS LEARNED & FUTURE CHALLENGES

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ABSTRACT

The Intelligent Tutoring System for Tactical Aircraft (ITS-AIR) is designed to enhance pilot learning while reducing lifecycle costs associated with on-site simulation operators and instructors. ITS-AIR is envisioned as an add-on system for future, existing and legacy simulators. SDS s rationale in producing the ITS-AIR system is based upon a divide and conquer methodology utilizing COTS & GOTS DIS/HLA resources coupled with simple small cooperative intelligent agents. The prototype ITS-AIR system presented in this paper can be logically viewed as two cooperative main modules. **SAM** the **S**ystems **A**utomation **M**odule that replaces the on-site simulation operators and **HIT** the **H**ierarchical **I**ntelligent **T**utor module that reduces the on-site instructor requirements.

SAM is an intelligent agent that provides the pilots with a simple Graphical User Interface (GUI) that starts and synchronizes all the ITS-AIR System components. For example, in the NAWC/TSD funded SDS, BMH and SOAR ITS-AIR Testbed (See Figure 2) SAM currently starts two LiteFlite™ Simulators, JSAF, SOAR, SOAR-Speak, ModIOS™, I-Matrix™, Academix™ and HIT. SAM also freezes, restarts and stops the components in a synchronous manner. Additionally, SAM is used by HIT to load and control lessons. SAM also contains **TCIA** the **T**emporal **C**ontrol **I**ntelligent **A**gent the controls the flow of simulated time throughout the distributed simulation architecture. TCIA services provide the HIT with the capacity to slow the pace of events for early skill acquisition phases, or present learning events in slow motion emphasizing the details that may not be easily perceived at normal real-time rates. TCIA services also provide the HIT with Above Real-Time Training (ARTT) Capabilities. ARTT has demonstrated to produce large training benefits (Guckenberger, Lane, Stanney 1992; Guckenberger and Crane 1997) and is envisioned to have even higher performance benefits when used in conjunction with HIT.

SAM provides the pilots with a simple GUI to log-in, select curriculum lessons, free-play or mission rehearsal modes. SAM and HIT allow the pilots to train in a user-friendly, non-threatening environment in which the student can be guided through training scenarios based on instructor defaults or dynamic configuration by the student. Performance data can be recorded into the students HIT database records via XML based on the preferences of the instructor and / or student. HIT supports:

- Expert Review - Presentation of experts doing tasks, monitor differences between current pilot performance and different levels of experts corresponding performance
- Intelligent tutoring options based upon pilot performance and pilot questions

HIT is actually composed of multiple components and simple cooperative intelligent agents utilizing XML resources.

The ITS-AIR Testbed will allow for the full integration and testing of various modular components of the ITS-AIR system. The Testbed will be fully utilized for experimentation and validation of the various Pedagogical Intelligent Agent technologies related to Intelligent Tutoring. It is anticipated that ITS-AIR will successfully address numerous requirements for Warfighters, utilizing products of PMA205, USAF DMT and NASA s Aviation Safety and Capacity programs.

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OVERVIEW

The Intelligent Tutoring System for Tactical Aircraft (ITS-AIR) is designed to enhance pilot learning while reducing lifecycle costs associated with on-site simulation operators and instructors. ITS-AIR is envisioned as an add-on system for future, existing and legacy simulators. SDS s rationale in producing the ITS-AIR system is based upon a divide and conquer methodology utilizing COTS & GOTS DIS/HLA resources coupled with simple small cooperative intelligent agents. The prototype ITS-AIR system presented in this paper can be logically viewed as two cooperative main modules. **SAM** the **S**ystems **A**utomation **M**odule that replaces the on-site simulation operators and **HIT** the **H**ierarchical **I**ntelligent **T**utor module that reduces the on-site instructor requirements.

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- Expert Review - Presentation of experts doing tasks, monitor differences between current pilot performance and different levels of experts corresponding performance
- Intelligent tutoring options based upon pilot performance and pilot questions
- Scheduling and Registrar functionality through Academix™ module
- Standards-Based Interface Control through the I-Matrix™ communications interface

HIT is actually composed of multiple components and simple cooperative intelligent agents utilizing XML resources and a relational database.

The prototype ITS-AIR methodology was selected based upon the authors many years of experience observing that monolithic do it all software constructs are costly, difficult to maintain or modify and frequently fail to meet user requirements. In the authors convictions, far too many current intelligent tutor projects waste time, resources and dilute their primary efforts by developing simulations, or student log-in software, or scoring or grade tracking software, or other computer generated force software that is unnecessary and of limited reuse. The authors strongly suggest that an add-on module Intelligent Tutoring System that works with existing resources is a more realistic training environment and ultimately a more useful software construct for military utilization. Accordingly, the ITS-AIR prototype and Testbed presented in this paper demonstrate such an add-on modular methodology in a DIS and HLA context that allows for plugging the system into existing networked simulation training environments.

BACKGROUND

The proliferation and effectiveness of deployed training systems is dependent upon the life cycle cost / benefit ratio of such training systems (e.g., DMT, TSTARS, etc.) Deployed training system benefits include but are not limited to reduced travel expenditures, reduction of personnel time lost at training locations, reduction of geo-specific training center costs, and increased availability of training on station. What have been lacking are methods and technologies to support deployed training systems operation in the reduced manning level environment of current military budgets. ITS-AIR innovations based upon GOTS and COTS technologies are based upon building cooperative constructs from DIS/HLA virtual and constructive simulators and resources, academics tools, and intelligent agents for tutors. The ITS-AIR construct and testbed provides a rapid prototyping environment, which will be used for research assessing an instructorless intelligent tutoring system for deployable tactical aircraft training systems. Specifically, the prototyped intelligent agents will be utilized for investigations into the reduction of support manning levels for deployed training systems. Further, Soar based AIR-SF and JSAF/ BMH tools will be used as the basis for After Action Review and mission rehearsal components including in-situ training. Other innovations include the reuse of the SDS LiteFlite“ Reconfigurable Flight Simulator with research and self-instructional features built for AFRL. LiteFlite“ will be leveraged as a placeholder for the DMT or TSTARS system planned for later studies. One of the key technologies being leveraged for the ITS-AIR research effort is SDS s Simulation and Intelligent Tutoring Tools such as LiteFlite“ Reconfigurable Flight Simulator and I-Matrix™, an Intelligent Agent Communications Architecture under development by SDS. LiteFlite“ has easy to use research features that include Excel spreadsheet input of performance criteria; Visual Basic Script of Real-Time Scoring input; Excel spreadsheet output of scored performance of any ownship variable / value or event criteria at any desire sampling frequency; and Self Instruction Strip Chart displays for students to measure their performance against expert performance complete with color coded bands for grading performance. Planned View Moving Map displays and Stealth Review / Monitoring are already supported for Microsoft s Direct Play (Modem and Internet), DIS and HLA. [Note: LiteFlite was selected based upon its availability and the authors familiarity. Its initial selection is only as a placeholder for later tactical aircraft simulations]

The ITS-AIR research team itself can be considered an innovation, bringing together a top research team to develop integrated products based upon human-centric design principles, simulation prototyping, usability analysis, intelligent agent technology, advanced cognitive modeling, and extensive military operational flight / instructional experience. The Integrated Product Development Team (IPT) is planned to consist of the Navy TPOCs and SMEs (on an as available basis); SDS International Inc.; Dr. Johnson of University of Southern California (USC); Soar Technology; and BMH Associates Inc.

The immediate significance of the proposed innovations are increased automation support for the DOD Acquisition Program PMA 205 products and reduction of manning levels with associated reduction in costs for Aviation Training Systems with the ultimate objective of developing an instructor-less and intelligent tutoring system for deployable tactical aircraft training systems. The later phases of the research study are planned for utilization and demonstrations in support of the NAVY TSTARS and USAF DMT training systems. Further, ITS-AIR is expected to expand to the generic case for the benefit of the entire simulation and training community. Rather than perpetuate the status quo of high-cost, high manning levels, geo-specific training centers, ITS-AIR will support low-cost, low manning levels, anywhere, anytime on-demand training and mission rehearsal. The ITS-AIR significance is enabling cost-effective, efficient simulation training and mission rehearsal for the masses in training centers, bases, and even homes.

ITS-AIR can provide a cost-effective approach to multiple levels of training, ranging from self-training/self-correction to automation of the evaluation of training effectiveness technologies. For example, automation of frame by frame comparison and scoring of the expert s position vs. the trainees can significantly improve not only the training itself but also the assessment of training value. Furthermore, automation of human performance measurements through existing tools, such as the SDS developed After Action Review (AAR) and Self-Instruction tools developed for AFRL, or the proposed Shadow Training technology, is not limited to laboratory/research environments. Rather, it is highly suitable for use in--and assessment of day-to-day activities experienced in operational environments. An eventual goal of the ITS-AIR system would be to provide a personalized instruction environment, utilizing intelligent agents, which would be equivalent to the current preferred method of select students taught by world class experts (e.g., TOPGUN, Weapons School). The key innovations of the ITS-AIR system are focused on reducing and / or replacing required support personnel, such as simulator operators, maintenance personnel and facilitators / instructors, while maintaining and enhancing the training effectiveness of deployed devices. It is anticipated that ITS-AIR will successfully address numerous requirements for Warfighters, utilizing products of PMA205, USAF DMT and NASA s Aviation Safety and Capacity programs.

PHILOSOPHY

The emphasis is on utilizing GOTS & COTS products as the basis for the ITS-AIR prototypes in keeping with the Navy investment strategy in commercial off-the-shelf (COTS) aircraft simulation technology deployable at sea. The high cost of computer hardware and software has historically driven up the cost of simulation systems. The requirement for instructors, operators, and maintenance personnel makes them expensive to operate in the field. New developments in COTS computer technology, self-diagnostic maintenance, self-calibrating visual display systems, on-line technical support, and on-site service contracts will dramatically reduce simulator costs in future years. The current situation is that many training devices rely on custom instructional systems, which require an instructor to operate the system and provide performance feedback to the trainee. The absence of a COTS Intelligent Tutoring Systems (ITS) product for flight simulators increases system development and operational costs, and reduces the capability to economically deploy the system. A generic, intelligent, instructor-less capability should improve usability, reduce costs, and improve the training effectiveness of new simulators.

METHODOLOGY

Self-Instructional Innovations

SDS has been assisting AFRL/HEA through a Historically Black College or University (HBCU) contract to develop a system at Tuskegee University for self-instructional PC based Pilot training with a low cost reconfigurable flight simulator, comparing expert vs. pilot performance on strip charts and Above Real-Time training (ARTT). [Note: NASA Dryden Flight Research Center also funds Tuskegee University and SDS in cooperative ARTT research.] Additionally the ITS-AIR research team has been experimenting with constructing intelligent agents with Java, with timed and change of state event triggers with the features of Agency, Intelligence and Mobility. Further, SDS has been utilizing Dr Stanney for Human Factors in general with emphasis on usability analysis. We are currently in the process of researching various GOTS and COTS available agent technologies for inclusion in the testbed, including SOAR and VIVIDS. These cognitive components will integrate with the I-Matrix™ product to communicate generically with the learning environment.

The aim and opportunity of SDS s proposed research is the near-term development of generic features, which will allow ITS-AIR to be easily adapted for new tactical aircraft training simulations. Utilizing the expertise and available COTS and GOTS tools of the research team, a common cross-platform interface for these generic features will be derived. This common interface will allow for the insertion of the intelligent operator component into any compliant test bed. The study is based on iterative refinement and early prototyping by leveraging SDS s LiteFlite“ Reconfigurable Flight Simulator with USC Intelligent Tutoring and STOW/BMH s tool sets to allow researchers, SMEs and pilots to work in a WYSIWYG environment. Past experience has shown that a dynamic working environment that promotes visualization and interaction accelerates the research process. The test-bed environment, coupled with the reuse of SDS tools, will enhance the program s accomplishments and facilitate a smooth transition to productization. The SAM and HIT architecture will be expanded on to include other areas of research including on-line learning and self-help environments. All research will be conducted with strict adherence to the scientific method.
An initial roadmap to achieve each autonomous agent is presented in the methodology section.

SAM (System Automation Module)

Capturing the knowledge domain of an on-site operator was the initial task of the research team members. Preliminary investigations into the operator knowledge domain indicated that a successful operator possesses knowledge of both the simulation program and the student s familiarity with the simulation. The research utilized the Unified Modeling Language (UML) USE cases as an appropriate first step in obtaining the requirements necessary to replicate an operator knowledge domain. Using the DMT and TSTARS programs as guides and LiteFlite“ as the functional placeholder, the team developed the requirements, sequences and dependencies necessary for ranking and developmental prototyping. Exciting avenues for exploration include use of a voice recognition tool (Soar/BMH) to interact with our students when they turn on the light switch in a pseudo-TSTARS room, SAM initializes the HIT dynamic autonomous student agents, and intelligent autonomous operator agents. The test-bed emulates the typical space constraints and ergonomic constraints encountered in deployed trainer systems such as the TSTARS program.

HIT (Hierarchical Instructional Tutor)

The HIT / SAM test-bed architecture is being utilized to explore the development of autonomous agents to enhance and optimize human learning, modify skill acquisition learning curves and enhance simulator utilization. UML USE cases are the primary research vehicle for assessing necessary and desirable components of an autonomous instructor agent. The ultimate goal is to increase simulator utilization and optimize skill development / retention while reducing operating costs. Reuse of developed tools and prior research by all team members are being utilized. The ITS architecture is summarized in figure 1, below.

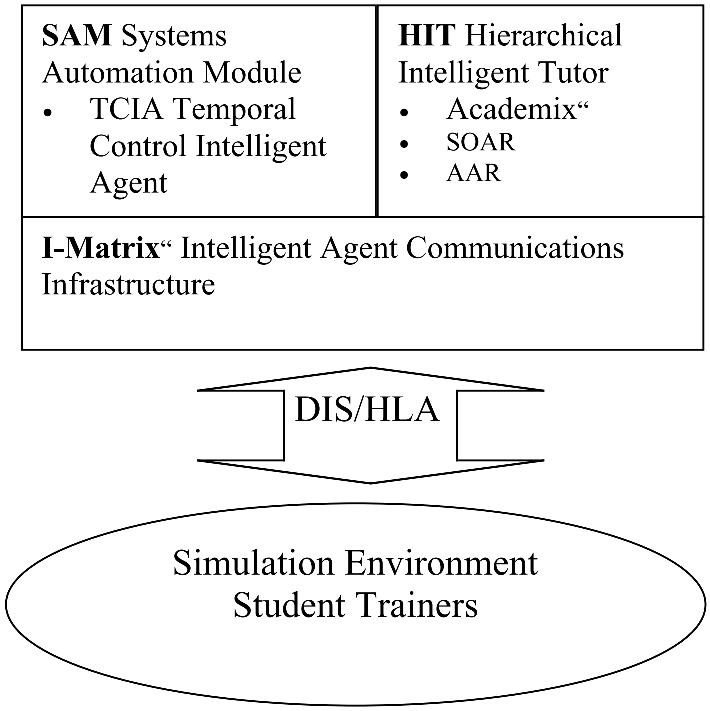

Figure 1 – ITS-AIR architecture.

I-Matrix“ – Intelligent Agent Communications Infrastructure

The I-Matrix™ product is being developed as a standards-based communications architecture in which Intelligent Agents can transmit and receive messages in a distributed environment. The infrastructure defines the communications among the agents and the operating / training environment. The I-Matrix™

Software bridges the gap between software agents written in various programming languages and the multitude of training system platforms in place. The standard communication tool used for the infrastructure is XML. SDS is actively expanding its Data Type Definition / ICD for inter-agent communication as well as agent / training environment. Any cognitive models that are implemented within the architecture can be easily adapted via the XML translation. In addition to communications standards, the system allows for cross-platform compatibility by implementing agents with JAVA. JAVA development is supported on several operating system platforms including major UNIX and Windows environments.

Future SAM Update – Reducing the Role of the Maintenance Personnel

After initial efforts at reduction / elimination of simulation operational personnel, an effort will be made to characterize desirable automated features for diagnosis and maintenance of the deployed simulator. These characterizations will be high level as it is thought that these features tend to be simulator specific and more dependent on specific hardware. Avenues for exploration include a portable PC with wireless camera connection to allow non-expert personnel to be walked through non-routine maintenance procedures by shore based experts, autonomous agents to monitor system performance and dynamic databases to predict normal life-cycle events. Extensive use of auto-convergence, automatic color matching and edge blending of displays can be exploited to enhance automated simulation features.

RESULTS AND DISCUSSION

The first phase of the study reported in this paper is in the context of ITS-AIR as a reconfigurable aircraft training device and mission rehearsal simulator. Specifically, ITS-AIR will is applied to a single aircraft type and a restricted set of mission tasks, it will have the capability to be extended to other aircraft types and a full range of missions without major software modification. The design example is tailored to the UCAV application but the concepts, principles and designs will be aimed at the generic case for future employment on a wide range of applications.

Figure 1 – Overview of the BOWMAN Syste

ITS-AIR capabilities include (but are not limited to)

Required Features	Applicable Existing GOTS & COTS Tools
SAM Control Of The Training Simulation	Soar, STEVE, JSAF/STOW tools, LiteFlite", TCIA, HIT, I-Matrix"
Windowed User Interfaces	Win2000, Linux, SDS s Fast Panel and ActiveX Plug-in Interfaces directly to LiteFlite and associated companion products (in C++, Visual Basic and Java)
Intelligent Mentoring	SOAR, STEVE, JSAF/STOW tools, VIVIDS
Performance Monitoring And Diagnosis	SOAR, STEVE, JSAF/STOW tools
Adaptive Training	Above Real-Time Training, STEVE, Adaptive Scenario Loading
Flexible Cognitive Models	SOAR, STEVE, JSAF/STOW tools
Rapid Reconfiguration For New Simulations	SDS s LiteFlite" Reconfigurable Flight Simulator is being used to exercise the prototyped ITS-AIR system in preparation for transfer to TSTARS and other DMT training systems
Scalability For Team/Crew Training	JSAF/STOW tools and SDS LiteFlite" Flight simulators are all designed as scalable DIS/HLA Team Training Products or place holders

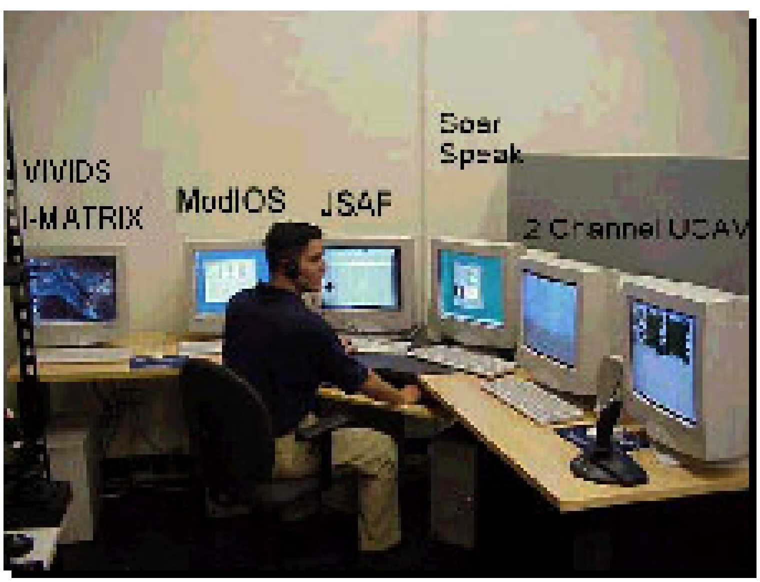

Figure 3 ITSAIR Testbed Orlando

LESSONS LEARNED

The ITS-AIR Test-bed relied upon the integration of many disparate technologies. The most difficult task involved with the integration is the communication of meaningful information among the systems. The scope of the effort encompassed man-in-the-loop simulators, Computer Generated Forces (JSAF/STOW), networked Intelligent Agents, and several networking protocols including DIS and HLA. The nature of the demonstration was to extract information regarding the student s interactions with the simulation, reason intelligently about the actions of the student, decide on an instructional course of action, and provide feedback to the student. During the process, questions immediately arose concerning how to extract data from the simulator, how to process that data into meaningful information, how to intelligently reason about the information in a timely manner, and how to provide appropriate feedback to the student if necessary. All of these technical hurdles underlied the basic premise of providing the student with a fulfilling training experience in which they would require no assistance, technically or instructionally, from a living person.

Data Capture

The very nature of simulation environments dictates a free-play, interactive learning environment that provides limitless options to the students and updates at up to sixty times per second and beyond. The problem scope, at its most robust implementation, involves a nearly limitless factorial of combinations for each student interaction with the simulated learning environment. The problem becomes one of abstracting the frame by frame interactions into meaningful time-snaps of information that relate to an identifiable activity such as reached waypoint . Our test-bed included our own simulator software that was accessible and configurable to our needs. To successfully apply our ITS to other simulators, we had to develop a standard interface that would allow the abstraction to take place regardless of the source of the data. I-Matrix™ supports the communication links needed to generically extract the data from disparate sources.

Data Conversion and Filtering

Once the data is being collected at appropriate intervals, the data must be abstracted to a level in which the intelligence of the system can act upon the information. This abstraction is taken care of through XML transformations (XSLT), which act on information from unique sources and conditionally evaluates the data according to preset criteria. This pre-processing of the data serves to weed out the superfluous data and leave only the pertinent information that will be intelligently reasoned upon. This filtering process, when done correctly, reduces the processing burden on the cognitive modeling engine in use.

Information Processing (Cognitive Reasoning)

Several intelligent tutoring models have been evaluated for use in the ITS test-bed. Each tutoring model has strengths and weaknesses. In addition cognitive models can vary from case-based, rule-based, and neural network engines. For the purposes of our test-bed, we chose an individual architecture and used that exclusively. The design, however, includes compatibility among several architectures, including custom agents and cognitive models. The flexibility is made possible the same way that several data sources can be managed through I-Matrix™. I-Matrix™ manages the inputs and outputs from the data sources of the training environment to the cognitive models of the Intelligent Agents. The complexities of such an implementation are numerous and are not taken lightly by the research team.

Intelligent Scenarios Lesson Learned

Ong and Ramachandran (2000) present a excellent overview of intelligent tutoring system. Their presentation of the importance of the scenario vs rules is excerpted below:

A common alternative to embedding expert rules is to supply much of the knowledge needed to support training scenarios in the scenario definition. For example, procedural task tutoring systems enable the course developer to create templates that specify an allowable sequence of correct actions. This method avoids encoding the ability to solve all possible problems in an expert system. Instead, it requires only the ability to specify how the learner should respond in a scenario. Which technique is appropriate depends on the nature of the domain and the complexity of the underlying knowledge.

Intelligence being built into the scenarios themselves is a key Intelligent Tutoring Lesson Learned concept that the authors suggest should be emphasized. Templates for allowable sequences as Ong and Ramachandran advocate is a good starting point. However, it is also essential for the Scenario development to occur with the Subject Matter Experts working closely and cooperatively with the Scenario development team towards the learning goals. Consider, the best human instructors develop their scenarios as learning experiences where the pilots selections can have rewarding desired outcomes and opportunities to make bad selections that result in some not so good outcomes. A example is a air-to- ground mission scenario where a

MiG target seems to be a slightly off course potential target that leads overly aggressive pilots into a SAM box ambush, if they are impulsive enough to take the bait.

SUMMARY

The ITS-AIR project is a first step in standardizing an Intelligent Tutor environment for simulation and training scenarios. The goal of the project is to apply the technology generically to several problem domains with the least amount of re-engineering possible. Our technique emphasized limiting our problem scope to a very specific area of interest and then working outward from that focus. Our architecture addresses the immediate concerns of the specific adaptation, yet plans for future expansion through the use of standardized communication technologies. The ITS-AIR test-bed can provide a cost-effective approach to multiple levels of training, ranging from self-training/self-correction to automation of the evaluation of WYSIWYG training effectiveness technologies. The flexibility of the test-bed allowed our team to experiment in the actual target environment without having to hypothesize about integration problems.

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