Expanding Domain Modeling in GIFT

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INTRODUCTION

The purpose of this paper is to update users of the Generalized Intelligent Framework for Tutoring (GIFT; Sottilare, Brawner, Goldberg, & Holden, 2012; Sottilare, Brawner, Sinatra, & Johnston, 2017, *in press*) on new and emerging capabilities to represent a broader variety of task domains in Intelligent Tutoring Systems (ITSs) in support of adaptive instruction. Adaptive instruction delivers content, offers feedback, and intervenes with learners based on tailored strategies and tactics with the goal of optimizing learning, performance, retention, and transfer of skills for both individual learners and teams. GIFT is a tutoring architecture that has evolved over the last five years with three primary goals: 1) reduce the time and skill required to author ITSs, 2) automate best practices of instruction in the policy, strategies, and tactics of tutoring, and 3) provide a testbed to assess the effectiveness of adaptive instructional tools and methods with respect to learning, performance, retention, and transfer of skills. Another overarching goal for GIFT has been to adapt ITSs to provide instruction in militarily-relevant training and educational domains.

The US Army Learning Model (ALM; U.S. Army Training & Doctrine Command, 2011) notes that training and education tools and methods must be of sufficient intelligence to understand the needs of individual learners and teams, and adapt to mitigate negative learner states, and to guide and tailor instruction in real time to optimize learning, performance, retention, and transfer of skills from instruction to operations. This is the basis of self-regulated learning (SRL) where Soldiers are expected to largely manage their own learning and career development through the growth of metacognitive (e.g., reflection), self-assessment, and motivational skills (Butler and Winne, 1995) with guidance from artificially-intelligent software-based agents. Effective guidance can only come from informed agents who fully understand the states, traits, and limitations of the learner along with subject matter expertise of the domain under training.

Currently, most ITSs are focused on cognitive task domains (e.g., problem solving and decision making) in academic subjects that primarily include software programming, physics, and mathematics. While there are many military task domains that involve cognitive skill development (e.g., military planning processes and assessment of battlespace strategies and tactics), many more involve interdependent team processes (e.g., building clearing) and psychomotor skills (e.g., marksmanship). It is for this reason that we desire to extend current capabilities in GIFT to support content delivery, assessment, and remediation processes for more complex team and psychomotor tasks. The following section describes some of the challenges to expanding domain modeling beyond cognitive tasks and beyond the current model of desktop training.

CHALLENGES IN EXPANDING DOMAIN MODELING

As GIFT has been designed to be largely domain-independent except for the domain model, the concept of domain modeling is vital. Research in domain modeling strives to make GIFT generalizable for multiple types of tasks (cognitive, affective, psychomotor, and social) and provides flexibility to facilitate the reuse of content and structure. In 2015, Sottilare, Sinatra, Boyce, & Graesser documented domain modeling goals/challenges and approaches. Goals/challenges follow:

- Understand and model the characteristics, similarities, and differences of military training domains (cognitive, affective, psychomotor, social, and hybrid) with respect to their associated knowledge representations to support more efficient and effective authoring, instruction, and evaluation of adaptive training tools and methods
- Understand and model the dimensions (definition, complexity, and dynamics) of training domain representations to extend the capabilities of traditional ITSs; thereby, supporting challenging, militarily-relevant training domains

Below are research approaches to modeling domain content and dimensions:

- Examine the efforts required to author domains of varying complexity, definition, and physical dynamics and identify methods
- Define methods to measure task domain complexity to allow comparative evaluation of different authoring systems and capabilities
- Examine domains for ill-defined and well-defined tasks to understand differences and support authoring processes for both
- Examine the composition of militarily-relevant training and education domains across the spectrum of cognitive, affective, psychomotor, and social tasks to understand requirements for authoring
- Discover/examine methods to match the nature of military tasks in training/educational environments and operational environments to optimize transfer of skills, and evaluate methods to determine the return on investment (ROI) for high levels of compatibility
- Discover methods to accurately assess learning and domain task performance in real-time
- Discover methods to promote optimal learning, performance, retention and transfer (on-the-job performance) across domains
- Discover tools and methods to support individual and team training (e.g., small unit and collective training) and education (e.g., collaborative learning and problem-solving) experiences

If we examine the complexity of tasks, we can see tasks that are trained exactly as they are executed in the operational environment. These tasks are the most dynamic and have the greatest chance to transfer skills from training to operations. Tasks where there is less of a match between training actions and operational actions have a lower opportunity for transfer, but are also less complex and therefore less expensive to build. Before we begin examining new and emerging domains, it is useful to the following hierarchy helps define complexity based on task dynamics:

- static training (e.g., desktop training), lower complexity, lower transfer potential; more cognitive
- limited dynamic (e.g., adaptive marksmanship training), limited movement, moderate transfer potential, mix of cognitive and physical
- enhanced dynamic (multi-learner tasks in instrumented spaces), operational movement in a restricted space, moderate to high transfer potential, mix of cognitive and physical
- in-the wild (instrumented learners), operational movement in an unrestricted space, high transfer potential, high degree of physical dynamics

The following sections describe areas of new or emerging capabilities to support the goal of expanding GIFT to a wider variety of task domains.

TUTORING MARKSMANSHIP: A PSYCHOMOTOR TASK DOMAIN

The most mature psychomotor domain in terms of research and development of a working prototype is marksmanship. GIFT now has a coordinated set of sensors that identify behaviors that are critical to successful marksmanship. The prototype has now been integrated with PEO STRI's Engagement Skills Trainer to demonstrate interaction of the learner with stationary targets, assessment of the learner's performance, and remediation of any detected errors by the tutor as shown in Figure 1.

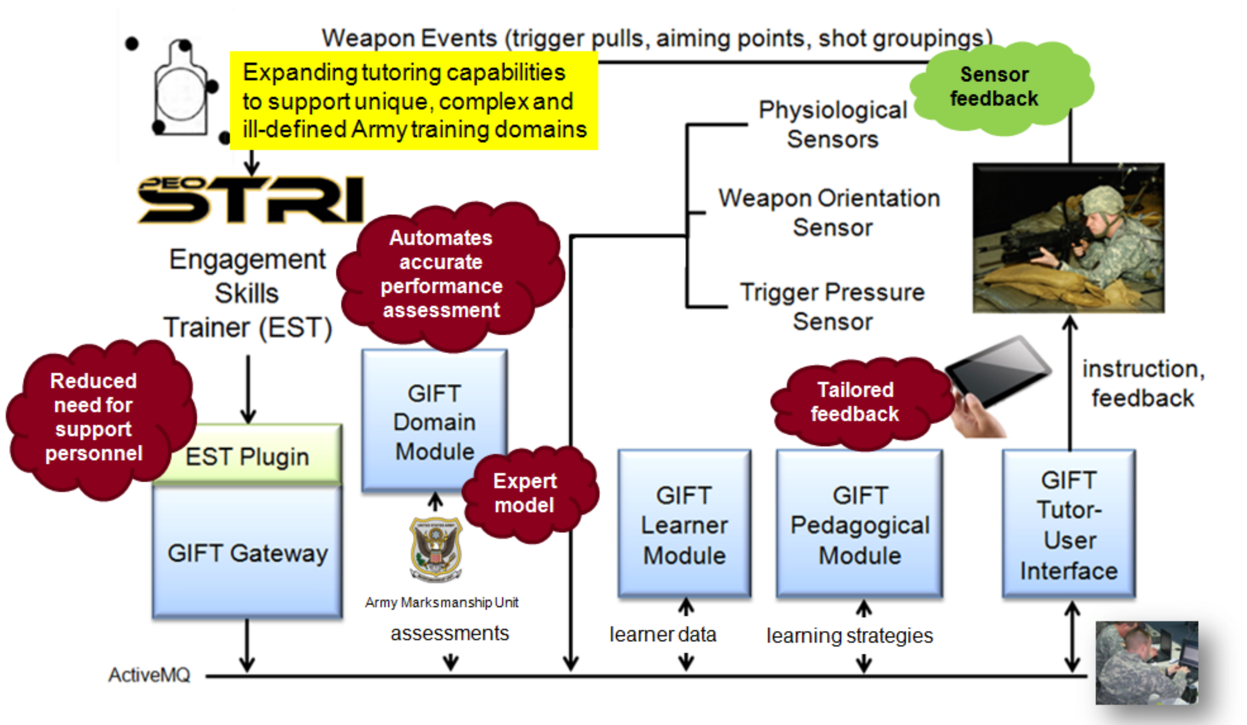

Figure 1. Interaction between learner, markmanship environment, and the ITS.

TUTORING MEDICAL TRIAGE AND HEMORRHAGE CONTROL

The adaptive instruction provided by Intelligent Tutoring Systems (ITSs) tailors direction, support, and feedback to enhance/maintain the learning needs (e.g., lack of knowledge or skill) of each individual. As noted earlier, ITSs are generally developed to support desktop instructional applications involving cognitive problem solving and decision-making tasks. Recently, GIFT has been used to provide tailored training military tasks using desktop applications (e.g., Virtual Battlespace and Virtual Medic). The degree of transfer of skills from training to operations is limited since training is more focused on the process and much less on the interaction between the learner and the virtual patient. For this reason, the military establishment requires adaptive instruction to extend beyond the desktop to be compatible with the physical nature of many tasks encountered.

In 2016, Sottilare, Hackett, Pike & Laviola examined how commercial sensor technologies might be adapted to work with GIFT and support tailored computer-guided instruction in the psychomotor domain for a military medical training task, specifically hemorrhage control. Toward this goal, they evaluated the usability and system features of commercial smart glasses and pressure-sensing technologies. Smart glasses were selected as the focus of this study over handheld mobile devices in order to promote a hands-free experience during the training of hemorrhage-control tasks on a mannequin. Pressure sensors were selected to provide direct measures of effectiveness during the application of tourniquets and pressure bandages in controlling blood flow. Their findings demonstrated the feasibility of using commercial technology to train hemorrhage control. Smart glasses could provide visual effects (e.g., wounds and bleeding) while pressure sensors could be directly integrated into tourniquets and bandages to relay data about wound pressure. A next step is to build a prototype and begin testing limitations (e.g., distance between pressure sensors and computational platforms (e.g., computers or smartphones)).

TUTORING SPORTS: PSYCHOMOTOR TASKS AND BREATHING

This year (2017) Kim, Dancy, Goldberg, & Sottilare asked the question: does tactical breathing during a psychomotor task influence skill development while under adaptive instruction? Tactical breathing is a is a specific breath-control technique used by individuals to perform a precision action required psychomotor task in a stressful environment (Neumann & Thomas, 2009; Neumann & Thomas, 2011). The focus of this research is to examine the the relationship between cognitive (e.g., attentional resources) and physiological (e.g., breathing) factors during the execution a psychomotor task (i.e., golf putting). It is not well understood that how the corresponding mechanisms of attentional control interact with the physiological factors as the learner progresses to the learning stage. If attentional capacity changes over time during the learning stage, an adaptive instructional system such as a GIFT-based tutor could provide tailored feedback to the learner to refocus their attentional resources. Next steps in this effort are to experimentally examine the relationship between attentional resources and a broader set of physiological factors in a stressful task environment.

TUTORING IN THE WILD: AUGMENTED REALITY ENVIRONMENTS

Intelligent Tutoring Systems (ITSs) have been shown to be effective in training tools for a variety of military tasks. However, these systems are often limited to controlled laboratory settings in which they exercising cognitive skills (e.g., decision-making and problem solving) at on desktop or laptop computers. These tools may potentially limit the learning and retention of military members who are training to master physical tasks or tasks with physical aspects (e.g., psychomotor tasks). Augmented reality, mostly real with virtual effects, presents the possibility of combining intelligent tutoring with hands-on applications in realistic physical environments. Sottilare & LaViola (2015) and LaViola, et al (2015) began to examine the use of an augment-reality based adaptive tutoring system for instruction in the wild, locations where no formal training infrastructure is present. One of their goals was to identify the challenges of transitioning from desktop tutoring to the wild. Another was to examine low cost commercial smart-glasses to understand their benefits and limitations. Virtual humans and virtual objects were placed in various locations within the lab. They found it was feasible to employ AR as a tutoring tool in a restricted laboratory environment in order to control lighting/contrast, the persistence of the environment, and power consumption. Vargas (2017, *in press*) began to examine how to author (create and place) virtual humans and objects in AR environments. Next steps are to evaluate what it will take to make the system portable for use in a variety of lighting conditions.

TUTORING TEAM TASKS: TEAMWORK AND TASKWORK

Currently, there are no tools or methods available in the public baseline for modeling or tutoring teams in GIFT. However, there are research initiatives focused on team modeling, and identification of teamwork and taskwork processes. The major goals/challenges for modeling teams of learners are similar to those for individual learners. In 2015, Goodwin et al documented team modeling goals/challenges and approaches. Identified goals/challenges follow:

- Real-time acquisition of team behavioral measures for application in machine learning classifiers
- Real-time classification of collective taskwork and teamwork states to support adaptive instructional decisions in complex environments
- Classification of team competency using long term individual team member data (e.g., achievements, demographics, traits) stored in learning management systems and individual record stores
- Maintaining the accuracy of classification methods in environments with data issues (e.g., small samples, missing or ill-defined data) and within complex systems
- Support of team instruction in militarily-relevant team task domains (e.g., building clearing, collaborative problem solving)
- Lack of capability to handle and process large amounts of structured and unstructured team data (also referred to as big data)
- Lack of an easily accessible, persistent, cost-effective, and low-overhead training environment for teams of learners

Below are research approaches to acquiring team data and accurately classifying team states:

- Evaluate the performance of unobtrusive sensors in dependably acquiring team behavioral data
- Evaluate the performance (accuracy) of machine learning classifiers for various states related to teamwork and collective taskwork performance
- Examine and validate the accuracy of semantic analysis and other classification techniques in classifying/predicting domain competency of teams based on their collective experiences/achievements
- Examine reinforcement machine learning techniques to continuously improve instructional strategy and tactic selection for team training and educational experiences
- Examine machine learning techniques for working with small samples, missing data or inaccurate data for teams of learners
- Examine opportunities to link GIFT Cloud with external individual training simulations and serious games to provide an easily accessible, persistent, cost-effective, low-overhead training environment for adaptive team instruction

One way of extending domain-independence to the modeling of teams is to separate domain-independent teamwork behaviors from task-specific, domain-dependent behaviors. Salas (2015) distinguishes teamwork, interactions between team members, from taskwork, behaviors demonstrated in executing the task. An examination of teamwork activities (e.g., coaching or conflict management) via a meta-analysis of the team training and performance literature led to the identification of several behavior markers for high performing teams (Sottilare, et al, 2017, *in review*). Next steps are to seek methods to unobtrusively acquire these behavioral markers in order to identify team states and subsequently assign the ITS to manage them.

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