Motivations for a Generalized Intelligent Framework for Tutoring (GIFT) for Authoring, Instruction and Analysis

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Abstract. Intelligent Tutoring Systems (ITS) have been shown to be effective tools for one-to-one tutoring in a variety of well-defined domains (e.g., mathematics, physics) and offer distinct advantages over traditional classroom teaching/training. In examining the barriers to the widespread use of ITS, the time and cost for designing and author-ing ITS have been widely cited as the primary obstacles. Contributing factors to time and cost include a lack of standards and minimal opportunities for reuse. This paper explores motivations for the development of a Generalized Intelligent Framework for Tutoring (GIFT). GIFT was conceived to meet challenges to: author ITS and ITS components, offer best instructional practices across a variety of training tasks (e.g., cognitive, affective, and psychomotor), and provide a testbed for analyzing the effect of tutoring technologies (tools and methods).

1 Introduction

GIFT [1] is a modular, service-oriented architecture developed to address authoring, instructional strategies, and analysis constraints currently limiting the use and reuse of ITS today. Such constraints include high development costs; lack of standards; and inadequate adaptability to support tailored needs of the learner. GIFT's three primary objectives are to develop: (1) authoring tools to develop new ITS, ITS components (e.g., learner models, pedagogical models, user interfaces, sensor interfaces), tools, and methods, and develop authoring standards to support reuse and leveraging external training environments; (2) provide an instructional manager that encompasses best tutoring principles, strategies, and tactics for use in ITS; and (3) an experimental testbed to analyze the effect of ITS components, tools, and methods. GIFT is based on a learner-centric approach with the goal of improving linkages in the adaptive tutoring learning effect chain in Figure 1.

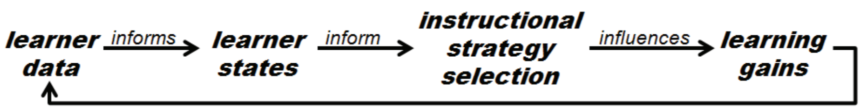

Figure 1: Adaptive Tutoring Learning Effect Chain [2]

GIFT's modular design and standard messaging provides a largely domain-independent approach to tutoring where domain-dependent information is concentrated in the domain module making most of its components, tools and methods reusable across tutoring scenarios.

2 Motivations for authoring tools, standards and best practices

The primary goal of GIFT is to make ITS affordable, usable by the masses, and equivalent (or better) than an expert human tutors in one-to-one and one-to-many educational and training scenarios for both well-defined and ill-defined domains. As ITS seek to become more adaptive to provide tailored tutoring experiences for each learner, the amount of content (e.g., interactive multimedia and feedback) required to support additional adaptive learning paths grows exponentially. More authoring requirements generally means longer development timelines and increased development costs. If ITS are to be ubiquitous, affordable, and holistically learner-centric, it is essential to for ITS designers and developers to develop methods to rapidly author content or reuse existing content. Overcoming barriers to reuse means developing standards. In this context, the idea for GIFT was born.

2.1 GIFT Authoring Goals

Adapted from Murray [3] [4] and Sottilare and Gilbert [5], the authoring goals discussed below identify several motivating factors for the development of authoring methods and standards. First and foremost, the idea of a GIFT is founded on decreasing the effort (time, cost, and/or other resources) required to author and analyze the effect of ITS, ITS components, instructional methods, learner models, and domain content. ITS must become affordable and easy to build so we should strive to decrease the skill threshold by tailoring tools for specific disciplines to author, analyze and employ ITS.

In this context, we should provide tools to aid designers, authors, trainers/teachers, and researchers organize their knowledge for retrieval and application at a later time. Automation should be used to the maximum extent possible to data mine rich repositories of information to create expert models, misconception libraries, and hierarchical path plans for course concepts.

A GIFT should support (structure, recommend, or enforce) good design principles in its pedagogy, its user interface, etc. It should enable rapid prototyping of ITS to allow for rapid design/evaluation cycles of prototype capabilities. To support reuse, a GIFT should employ standards to support rapid integration of external training/tutoring environments (e.g., serious games) to leverage their engaging context and avoid authoring altogether.

2.2 Serious Games and ITS

Serious games, which are computer-based games aimed at training and education rather than pure entertainment, are one option for reuse if they can easily be integrated with tutoring architectures like GIFT. Serious games offer high-level interactive multi-media instructional (IMI) content that is engaging and is capable of supporting a variety of scenarios with the same basic content. While most serious games offer prescriptive feedback based on learner task performance, the integration of serious games with ITS opens up the possibility of more adaptive feedback based on a more comprehensive learner model.

In order to facilitate the use of serious games in a tutoring context (game-based tutoring), standards are needed to support the linkage of game actions to learning objectives in the tutor. To this end, Sottilare and Gilbert [5] recommend the development of two standard interface layers, one layer for the game and one for the tutor. The game interface layer captures entity state data (e.g., behavioral data represented in the game), game state data (physical environment data), and interaction data, and passes this information to the tutor interface layer. The tutor interface layer passes data from the game to the instructional engine which develops strategies and tactics (e.g., feedback and scenario changes) which are passed back to the game to initiate actions (e.g., non-player character provides feedback or challenge level of scenario is increased).

Additional options for reuse should be explored to minimize/eliminate the amount of authoring required by ITS designers and developers. The ability to structure approaches for configuring a variety of tutoring experiences and experiments is discussed next.

2.3 Configuring tutoring experiences and experiments

Another element of authoring is the ability to easily configure the sequence of instruction by reusing standard components in a script. This is accomplished in GIFT though a set of XML configuration tools used to sequence tutoring and/or experiments. Standard tools include, but are not limited to functional user modeling, learner modeling, sensor configuration, domain knowledge file authoring, and survey authoring which are discussed below.

While not yet implemented in GIFT, functional user models are standard structures and graphical user interfaces used to facilitate tasks and access to information that is specific to the type of user (e.g., learners, subject matter experts, instructional system designers, system developers, trainers/instructors/teachers, and scientists/researchers).

Learner models are a subset of function user models used to define what the ITS needs to know about the learner in order to inform sound pedagogical decisions per the adaptive tutoring learning effect model. The learner configuration authoring tool provides a simple tree structure driven by XML schema which prevents learner model authoring errors by validating inputs against the learner model XML schema. This configuration tool also provides ability to validate the learner model using GIFT source without having to launch the entire GIFT architecture. Inputs to the learner modeling configuration include translators, classifiers, and clustering methods which use learner data to inform learner states (e.g., cognitive and affective).

The sensor configuration authoring tool allows the user to determine which sensors will be used during a given session and which translators, classifiers, and clustering methods the sensor data will feed. Again, this is an XML-based tool which allows the user to select a combination of behavioral and physiological sensor to support their tutoring session or experiment. Several commercial sensors have been integrated into GIFT through plug-ins.

Survey authoring is accomplished through the GIFT survey authoring system (SAS) which allows the generation and retrieval of questions in various formats (e.g., true/false, multiple choice, Likert scales) to support assessments and surveys to support tailoring decisions within GIFT. Through this tool, questions can be associated with assessments/surveys and these in turn can be associated with a specific tutoring event or experiment.

Domain authoring is accomplished through the domain knowledge file authoring tool. This tool allows an instructional designer to sequence events (e.g., scenarios, surveys, content presentation). GIFT currently support various tutoring environments expand the flexibility of course construction. These include Microsoft PowerPoint for content presentation, surveys and assessments from the GIFT SAS, serious games (e.g., VMedic and Virtual BattleSpace (VBS) 2). More environments are needed to support the variety of tasks that might be trained using GIFT.

3 Motivations for expert instruction

Significant research has been conducted to model expert human tutors and to apply these models to ITS to make them more adaptive to the needs of the learner without the intervention of a human instructor. The INSPIRE model [6] [7] is noteworthy based on the extensive scope of this studies that led to this model. Person and others [8] [9] seek to compare and contrast how human tutors and ITS might most effectively tailor tutoring experiences.

For its initial instructional model a strategy-tactic ontology, the *engine for Macro-Adaptive Pedagogy* (eMAP), was developed based on Merrill's Component Display Theory [10], the literature, and variables that included the type of task (e.g., cognitive, affective) and instruction (e.g., individual, small group instruction). Instructional strategies are defined as domain-independent policies that are implemented by the pedagogical engine based on input about the learner's state (e.g., cognitive, affective, domain-independent progress assessment (at expectation, below expectation, or above expectation)). Strategies are recommendations to the domain module in GIFT which selects a domain-dependent tactic (action) based on the strategy type (e.g., prompt, hint, question, remediation) and specific instructional context, where the learner is in the instructional content.

A goal for GIFT is for it to be a nexus for capturing best practices from tutoring research in a single place where scientists can compare the learning effect of each model and then evolve new models based on the best attributes of each model analyzed. To support this evolution, GIFT includes a testbed methodology called the *analysis construct* which is discussed below.

4 Motivations for an effect analysis testbed

As noted in the previous section, GIFT includes an analysis construct which is not only intended to evolve the development of expert instructional models, but is also available to analyze other aspects of ITS including learner modeling, expert modeling, and domain modeling. The notion of a GIFT analysis construct shown in Figure 2 was adapted from Hanks, Pollack, and Cohen's testbed methodology [11].

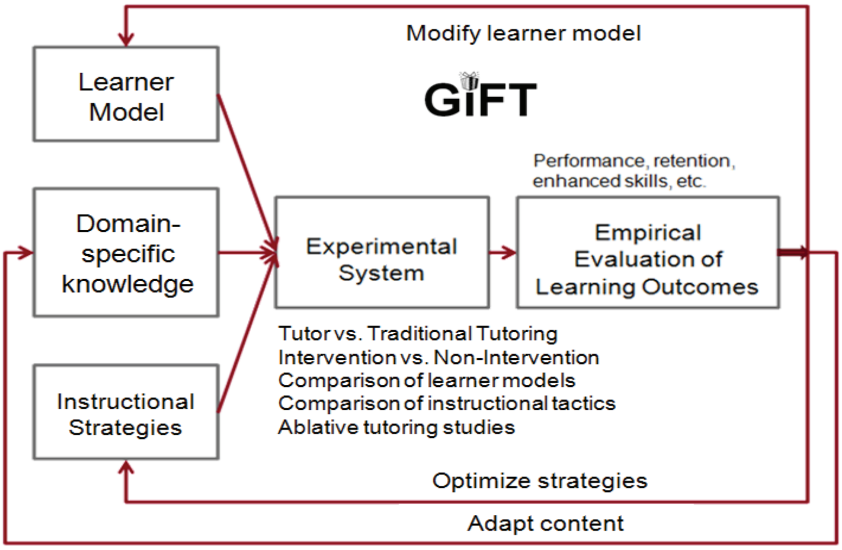

Figure 2: GIFT analysis construct

A great benefit of GIFT's analysis construct it is ability to conduct comparisons of whole tutoring systems as well as specific components (either entire models or specific model elements). To date, ITS research has been limited in its ability to conduct such comparative analyses due to the high costs associated with redesign and experimentation. This construct can be leveraged to assess the impact and interplay of both learner characteristics directly contributing to the learning process (i.e., abilities, cognition, affect, learning preferences, etc.) and those that are external and indirectly effect the learning process (i.e., perceptions of technology, the ITS interface, and learning with technology, etc.). Similarly, GIFT can provide formative and summative assessments to identify the influence of various instructional strategies and tactics; based on these assessments, GIFT is able to better improve and guide instruction dynamically and more effectively.

Across all levels of education and training populations, regardless of the mode of instruction (i.e., live, virtual, or constructive), a paradigm shift in the learning process is occurring due to the evolution of technology and the increase in ubiquitous computing. This notion has become noticeably apparent over the last few years. Even Bloom's revised taxonomy has been recently updated to account for new actions, behaviors, processes, and learning opportunities brought forth by web-based technology advancements [12]. Moreover, with the increasing recognition of the importance of individual learning differences in instruction, GIFT can ultimately be able to support the educational framework and principles of the universal design for learning (UDL) [13, 14]. This framework highlights the need for multiple means of r*epresen-*

tation, *expression*, and *engagement* to reduce barriers of learning and provide fruitful learning experiences for all types of learners. While this concept has evolved over the past decade, practicality and experimentation to progress this notion to true reality has been limited. However, GIFT's analysis construct can be used to access the effectiveness of UDL principles in an empirically-driven fashion.

5 Expanding the horizons of ITS through future GIFT capabilities

The potential of GIFT is dependent on two primary objectives: 1) focus research and best practices into authoring, instructional, and analysis tools and methods within GIFT to enhance its value to the ITS community and 2) expanding the horizons of traditional ITS outside the bounds of traditional ITS. This section concentrates on examining areas for future development which will expand the current state-of-practice for ITS including tutoring domains, interaction modes, and automation processes for authoring.

The application of ITS technologies has largely been limited to one-to-one, well-defined tutoring domains where information, concepts, and problems are presented to the learner and the learner's response is expected to correspond to a single correct answer. This works well for mathematics, physics and other procedurally-driven domains (e.g., first aid), but not as well for ill-defined domains (e.g., exercises in moral judgment) where there might be more than one correct answer and these answers vary only by their level of effectiveness. It should be a goal of the ITS community to develop an ontology for use developing and analyzing tutors for ill-defined domains.

Traditional tutors have also been generally limited to static interaction modes where a single learner is seated in front of a computer workstation and interaction is through a keyboard, mouse, or voice interface. Methods to increase the learner's interaction and range of motion are needed to move ITS from cognitive and affective domains to psychomotor and social interaction domains. It should be a goal of the ITS community to develop additional interaction modes to support increasingly natural training environments for both individuals and teams as shown in Table 1.

Interaction Mode	Environment	Learner Position	Learner Motion	Sensors	Sensory Interaction	Individual /Team
static	indoor	seated	head motion, posture changes, gestures	desktop sensors (e.g., eye tracker, head pose estimation)	visual, aural, olfactory	individuals and network-enabled teams
limited kinetic	indoor in confined instrumented spaces	standing, crouching, kneeling, laying	same as static mode plus limited locomotion	same as static mode plus motion capture	visual, aural, olfactory, haptic	individuals and co-located teams
enhanced kinetic	indoor/outdoor in confined instrumented spaces	standing, crouching, kneeling, laying	same as static mode plus full locomotion	same as static mode plus motion capture	visual, aural, olfactory, haptic	individuals and co-located teams
in the wild	outdoor in unrestricted, uninstrumented spaces	standing, crouching, kneeling, laying	unrestricted natural movement	portable sensor suites including motion capture	visual, aural, olfactory, haptic	individuals and co-located teams

Table 1. ITS interaction modes

Automation processes should be developed to support authoring of expert models, domain models, and classification models for various learner states (cognitive, affective, and physical). Data mining techniques should be optimized to define not only expert performance, but also levels of proficiency and expectations based on a persistent (long-term) learner model. Again, data mining techniques are needed to reduce the time and cost to author domain models including automated path planning for courses based on the hierarchical relationship of concepts, the development of misconception libraries based on course profiles, feedback libraries (e.g., questions, prompts) based on readily available documentation on the internet and from other sources .

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