Potential to Migrate ElectronixTutor to GIFT

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INTRODUCTION

Integrating disparate learning resources into a common framework presents several standard challenges. The learning resources are potentially diverse: texts, videos, diagrams, VR, open-ended and multiple-choice questions, natural language tutoring, simulations, and so on. How do we equate progress from one system to another? How do we assess a learner's progress within a learning resource and across resources? How do we recommend the best way forward for the learner? How do we handle different roles of users? All these critical questions have answers arising from the structure of the Generalized Intelligent Framework for Tutoring (GIFT; Sottilare et al., 2012a; 2013). However, if a system has not been created in GIFT from the ground up, the potential for migrating into that structure requires careful consideration.

ElectronixTutor represents the culmination of several years of development in electrical engineering intelligent tutoring systems (ITS) (Graesser et al., 2018). In the Office of Naval Research STEM Grand Challenge, the University of Memphis is leading an effort to integrate several separately developed computer-based learning aids on the topic of electronic circuits. The resulting system constitutes an expansive, adaptive pedagogical tool with the potential to substantially elevate conventional instruction. This paper discusses the commonalities and differences of ElectronixTutor and GIFT, with an eye toward migrating the innovative functionality and breadth of the former into the standardized structure established by the latter. There are two primary reasons for this migration: (1) To improve the quality of existing content by following GIFT standards, and (2) To allow easier expansion of content and learning resources.

COMMON FEATURES IN ELECTRONIXTUTOR AND GIFT

Current implementation of ElectronixTutor is in the form of Moodle (version 3.4.1). Moodle (Dougiamas & Taylor, 2003) is a learning platform or course management system. It is a free open source software package designed to help educators create effective online courses based on sound pedagogical principles (http://www.moodle.org) and it is now the most popular adapted open source learning management system worldwide, notably used by US government agencies such as Advanced Distributed Learning and the Office of Personnel Management.

GIFT (www.gifttutoring.org) is an empirically-based, service-oriented framework of tools, methods and standards to make it easier to author computer-based tutoring systems (CBTS), manage instruction and assess the effect of CBTS, components and methodologies (Sottilare et al., 2012b). GIFT is being developed under the Adaptive Tutoring Research Science & Technology project at the Learning in Intelligent Tutoring Environments Laboratory, part of the U.S. Army Research Laboratory's Human Research and Engineering Directorate.

There are high-level similarities between GIFT and ElectronixTutor. The similarities include, but not limited to:

1. ElectronixTutor (as a Moodle implementation) and GIFT are open source and highly used by learning organizations. While Moodle is used widely by various learning organizations, ElectronixTutor and GIFT are primarily for the government/military of the United States.
2. ElectronixTutor (not necessarily Moodle) and GIFT are especially designed to integrate theory-driven, research-based learning resources.
3. ElectronixTutor and GIFT use the same standards-based learning behavior data repository. ElectronixTutor utilizes a module to connect Experience Application Programming Interface (xAPI, Advanced Distributed Learning, 2016) and a Learning Record Store (LRS, such as LearningLocker, https://learninglocker.net/). GIFT has a utility that sends xAPI statements to the LRS.
4. ElectronixTutor and GIFT have a Learning Content Management System with built-in authoring tools for native learning resources.

DIFFERENCES BETWEEN ELECTRONIXTUTOR AND GIFT

There are a few distinctive features that differentiate ElectronixTutor (Moodle) and GIFT that need special attention when we migrate ElectronixTutor to GIFT. Some of the distinctions are technological in nature, whereas others are based on application details.

1. Moodle and GIFT are implemented using different underlying technologies. The Moodle interface is HTML5 generated by PHP pages with a backend mySQL relational database. The open source nature is applicable to almost every aspect of the application, including module integration and a look & feel theme integration (and responsive design) that fits a variety of client platforms. GIFT was originally designed for military use and has much more restricted underlying technology. It is less flexible, but more stable with specially designed modules.
2. Moodle is optimized as an Internet application and best used as a browser-based application[1], such that there are no limitations on the source of the learning material as long as it is accessible. GIFT has two versions: a cloud-based version and standalone version. While the cloud-based version is similar to Moodle, where there are no special limitations on the source of the learning content, the stand-alone version limits the source of the learning content. This limitation requires that all learning resources are from authenticated sources (in the current implementation of GIFT, they need to be from *.gifttutoring.org). This limitation will have some impact when we migrate ElectronixTutor to GIFT, if we want to have a GIFT version of ElectronixTutor as a standalone learning platform.
3. The GIFT domain knowledge is an XML file that contains the information needed to execute a single lesson. The information in this file is essential for other GIFT modules, such as the learner module and the pedagogy module. ElectronixTutor does not have (and is not intended to have) detailed information within each of the integrated learning resources. For example, when ElectronixTutor selects one of its component resources, such as AutoTutor or Dragoon, ElectronixTutor only uses limited information from the instantiated lesson because it is run on a different server and may use a different pedagogy. ElectronixTutor only requires that the learning resource returns a value of 0 to 1 on an associated knowledge component and/or topic.

SYSTEM MAPPING FROM ELECTRONIXTUTOR TO GIFT

Given the similarities and differences between Moodle-based ElectronixTutor and GIFT detailed above, we consider the following mappings between ElectronixTutor and GIFT.

[1] There are mobile applications made for Moodle, so there is a non-browser version of Moodle. However, the viewing of the learning content still uses a browser on mobile devices.

From ElectronixTutor Knowledge Components to GIFT Concepts

The substantial challenge in creating a single, sensibly integrated system like ElectronixTutor includes determining a way to have the component systems communicate with one another in a mutually comprehensible way. To do this, we use Knowledge Components (KCs) as basic units at the conceptual level (Koedinger, Corbett, & Perfetti, 2012). These KCs map onto skills or information in electrical engineering and periodically appear in a given learning resource. Each learning resource can contribute a score (varying from 0 to 1) on a given KC or combination of KCs for a problem presented to the learner. Scores contribute to the learner's level of mastery on that KC.

KCs are analogous to the GIFT *concept* whose assessments are conveyed via game state messages. This structure allows them to be integrated as game state messages with two variables: name and value. In a migrated GIFT/ElectronixTutor system, the *MessageTypeEnum* would be updated to include "SaveKCScore" as a message type, which would be the message type sent each time a learner completes an item and generates a KC (concept) score. Conditions that assess the game state messages could simply return the name/value pair provided.

From ElectronixTutor Learning Resources to GIFT Modules/Lessons

ElectronixTutor includes several distinct learning resources that range from ITSs to conventional learning aids. They include simple multiple-choice questions that provide feedback and adaptivity (BEETLE-II, LearnForm), questions on skill building (ASSISTments), component manipulation and simulated circuit problems (Dragoon), and conversational deep reasoning and knowledge checks (AutoTutor). These intelligent and adaptive systems complement more traditional static resources such as topic summaries and Navy manual readings (NEETS). These learning resources are analogous to the GIFT Learner Module. Each learning resource could be integrated as a course object.

Of all these modules, some (such as Dragoon and ASSISTments) are integrated as external applications. Others (hypertext such as videos, slides, etc.) can be re-authored and improved using existing GIFT course objects for topic introductions, and conventional surveys or tests for assessments. The most complicated resource, AutoTutor, is already an object as part of GIFT. As we have pointed out earlier, if ElectronixTutor resources are external (such as Dragoon and ASSISTments), they will not be available for the standalone GIFT unless they are implemented with the authenticated servers (such as *.gifttutoring.org).

From ElectronixTutor Resource Organization to GIFT Domain Course File

In ElectronixTutor, learning resources are organized by our Recommender System, combining typical course progression and user characteristics to identify optimal next steps. These take the form of Topic of the Day and Recommended Items. Users can also self-direct learning. Within GIFT modules, learning resources within a course are organized by a domain course file. A domain course file is an XML file that contains the information needed to follow a single course, which may contain one or more lessons. The domain course file allows substantial control and flexibility in determining the flow between course objects. Externally integrated learning resources and GIFT-native resources are organized in the domain course file (in the form of XML). ElectronixTutor's resource organization and GIFT domain course file can be made structurally equivalent, so that ElectronixTutor's Recommender System can be mimicked by GIFT.

Topic of the Day

Determining what content to present to the learner at a given time is handled by our Recommender System. This pedagogical component considers a typical progression through electrical engineering education (roughly equivalent to a syllabus), where the learner has exhibited proficiency (from the Learning Record Store), and on which types of learning resources the learner has performed well or poorly. Topics always begin with a topic summary to orient (or reorient) the learner, then progress to a conversational reasoning question. These fall roughly in the upper-middle of the difficulty spectrum among the ITSs and hold the most potential for discriminating the level of proficiency among aspects of a single question. Based on performance, the Recommender System can send users "up" to the most difficult Dragoon problems, or "down" to multiple choice, decomposed circuit problems, skill builder items on Ohm's or Kirchhoff's laws, and possibly to summary static readings. This process involves differential determinations based on KCs constituent to the topic, so excellence in one area does not supersede the learning trajectory of another topic. The selection of learning resources for the topic of the day could be handled in GIFT's *pedagogical module.*

Recommended Items

Recommended items are generated from a combination of learner KC scores and pre-defined rules. Among these rules, topics are repeated if a learner's topic performance score falls below a threshold. Next there is a focus on underperforming knowledge components. Topics with medium performance scores and individual knowledge component scores below a threshold are recommended. In addition, we include an option to "push the envelope", where learners who often perform above a threshold receive resources that have a higher intrinsic difficulty. Finally, we have motivated and unmotivated "bottom dwellers", where bottom dweller is defined by topic performance scores often occurring below a threshold whereas motivation is determined by falling outside of processing time thresholds. The Recommender System is more complex than expressed here, but it is beyond the scope of this document to give a full specification.

These rules that the Recommender System uses are analogous to some but not all of the GIFT *strategies.* More generally, the Recommender System is handled by GIFT's pedagogical module and could be encoded as such in our migration. Further, the Recommender System's consideration for learner aptitude on various learning resources could dovetail with the ICAP framework (Chi & Wylie, 2014) available within GIFT. This framework delineates stages of interactivity with a learning system—interactive, constructive, active, and passive—that correspond neatly with current learning resources.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

ElectronixTutor is currently implemented within the open source Moodle infrastructure. Moodle provides different user roles, a common housing for learning content (in the "activity window"), and a broad community of users from which to draw inspiration or consult on obstacles. But Moodle does not afford analysis and alteration at a fine-grained level, a positive feature of GIFT (Sottilare et al., 2013). This paper identifies some of the structural similarities of ElectronixTutor and GIFT at a high-level specification with the ultimate goal of migration to GIFT. Our focus now turns to how that migration can proceed.

The challenges listed above, and their respective solutions in the current manifestation of ElectronixTutor, have many similarities to the GIFT architecture. First, GIFT's User Module is directly analogous to our Learning Record Store. Both use xAPI and serve the purpose of informing the system of user

characteristics relative to the system. The Domain Module in GIFT corresponds closely to the knowledge components and topic mastery adopted in ElectronixTutor. These domain-specific aspects of learning serve as the currency to evaluate learner progress. That progress is managed in GIFT by the Pedagogical Module, structurally similar to the Recommender System described above.

We are exploring the process of migrating ElectronixTutor from the Moodle infrastructure to GIFT. The primary challenges lie in the details. For example, the custom-made Recommender System serves a similar function to the Pedagogical Module, but the pedagogical rules are not exactly the same. Likewise, Moodle presents the Learning Resources in an idiosyncratic way, with unclear mappings to GIFT interface structures. This paper describes a preliminary evaluation of the challenges and opportunities for integration of the ElectronixTutor system within GIFT.

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