Architecture and Ontology in the Generalized Intelligent Framework for Tutoring: 2018 Update

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INTRODUCTION

The first version of the Generalized Intelligent Framework for Tutoring (GIFT) was released to the public in May of 2012. One year later, the first symposium of the GIFT user community was held at the Artificial Intelligence and Education conference in Memphis, Tennessee. Since then, the GIFT development team has continued to gather feedback from the community regarding recommendations on how the GIFT project can continue to meet the needs of the user community and beyond. This current paper continues the conversation with the GIFT user community in regards to the architectural "behind the scenes" work and how the GIFT project is addressing the user requirements suggested in the previous GIFTSym5 proceedings. The development team takes comments within the symposium seriously, and this paper serves to address requirements from prior years.

As a follow up to the "GIFT 2015 Report Card and State of the Project" (Brawner & Ososky, 2015), the GIFT 2016 Community Report (Ososky & Brawner, 2016), and the GIFT 2017 Architecture Report (Brawner, Heylmun, & Hoffman, 2017), the feature requests and responses have been broken out among a number of papers, and into logical sections of this work. This paper discusses the ongoing architectural workings and changes in support of the various sets of projects. The number of projects which the GIFT overall projects is now well over 50, which represents a) the inability for significant direct support of any individual project and b) the relatively little support that individual projects need to be successful. GIFT generally works well enough to support research studies without direct developer guidance or specifically developed features.

The research and technology innovation efforts presented in the current document include those that are informed by the GIFT user community, and only represent a fraction of the overall research, development, and implementation work associated with GIFT. We invite the reader to review the other chapters in this volume, publications on GIFTTutoring.org, and other references described below, to get a sense of the total body of work on the GIFT project. Major themes in this current, 2018 GIFT report include tighter integration with wide-scale systems such as EdX and LearnSphere, further work in enhancing authoring, significant load tests for supporting many simultaneous users, the first and second GIFT Summer Camps, an upcoming shift to better conversational agents, and the move to individualized training for teams and during psychomotor tasks.

WELCOME

First, to the new members of the GIFT community and new GIFT users – Welcome! There are a number of recommended resources that will help to orient you to this project and ecosystem. GIFT has come a long way since its original goals were defined in its description paper (Robert Sottilare, Brawner, Goldberg, & Holden, 2012). First, we would encourage you to simply get started, as the tools and example courses have been designed to try to be as easy as possible for the creation of intelligent tutoring systems.

If you struggle with any individual aspect of the system, however, the team has produced short "how to" videos to try to help around the sticking points. There are now around 20 such videos, available at the following youtube channel URL: https://www.youtube.com/channel/UCWtI_V8f2mN5XD6h2lCjsAA/videos, which is the first result if you search "Generalized Intelligent Framework for Tutoring Youtube" on Google. If you would like additional help getting started, please consider the GIFT Quick Start Guide (Ososky, 2016) as another place to start.

In addition to a Quick Start Guide, usable tools, and videos, there is support for developers in the help forums and documentation. The GIFT user community is also invited to ask questions and share your experiences and feedback on our forums (https://gifttutoring.org/projects/gift/boards). The forums are actively monitored by a small team of developers, in addition to a series of Government project managers. The forums are a reliable way to interact with the development team and other members of the GIFT community. The forums, at the time of this writing, have over 1200 postings and responses. Documentation has been made freely available online at https://gifttutoring.org/projects/gift/wiki/Documentation, with interface control documentation https://gifttutoring.org/projects/gift/wiki/Interface_Control_Document_2018-1, and a developer guide https://gifttutoring.org/projects/gift/wiki/Developer_Guide_2018-1. These documents are updated each software release.

CLOUD GIFT GENERAL REPORTING

Cloud GIFT has now been up and running for the last two years. Increasingly, users start on the Cloud GIFT instance to make and take their first courses. With minimal outages, the system has now been up for a number of years. While initially envisioned as a "try before you buy" program (Brawner & Ososky, 2015), user expectations and general usability have demanded more mature software functionality from this research project. We have responded to the community demand for reliability in the Cloud GIFT instance by increasing its accessibility significantly. We, the development team, did not anticipate that users would author surveys with multiple hundreds of questions, open the system up to 100+ users on Amazon Mechanical Turk simultaneously, or other relatively high-demand tasks. This is a good problem to have, and we have taken several actions to harden the system to the level of robustness demanded from the community.

First, updates to GIFT Cloud now significantly precede the updates to the downloadable GIFT. Downloadable GIFT still operates on the 12-month developmental cycle, while Cloud GIFT is now operating on a 7-day release cycle. This effort has required significant re-tooling to move to a dev-desk, dev-cloud, and production model. As a byproduct, the team responds much quicker to bug requests. These changes are transparent to the end users but involve significant effort from the team. The latest stable regression-tested GIFT release is still available for download at gifttutoring.org, but a clone of what is available at cloud.gifttutoring.org is always available upon request.

Second, as part of the move to Cloud GIFT developmental cycles, we have been coordinating stress tests in order to identify system weaknesses and harden against them. Early weaknesses were identified in survey editing, survey requests, course validation, content upload, and other database-intensive requests. One initial stress tests of the system showed as few as 6 simultaneous users could successfully perform database-intensive operations. Modern tests after performance improvements have been made, at the time of writing, are reporting on the order of magnitude of 100 simultaneous users. These changes are transparent to the end users but involves significant effort from the team.

Third, as a part of hardening the system for research, the end use capability has been the ability to run educational experiments with cloud-deployed software instantaneously across the country. This capability is relatively mature, and the author is aware of several such experiments which have been run with 100+

users, from the teams at Carnegie Mellon University (Aleven et al., 2017), the University of Central Florida's Institute for Simulation and Training (Biddle, Lameier, Reinerman, Matthews, & Boyce, 2018), the Eduworks team (Robson, Ray, Sinatra, & Sinatra, 2017), the Aptima team (Brawner, Carlin, Oster, Nucci, & Kramer, 2018; Carlin, Nucci, Kramer, Oster, & Brawner, 2018), and the team at North Carolina State University (Rowe, Pokorny, Goldberg, Mott, & Lester, 2017). This capability is available for the general public.

Virtual Machines Available Upon Request

As part of the move to Cloud GIFT, we have a number of specialized processes which run in the background. Figure 1 shows the current structure of the Virtual Machine (VM) instances which operate Cloud GIFT. At its basic level, GIFT runs on two VMs; a Windows VM for all of the core GIFT features, and a Linux VM hooked up to an Amazon Relational Database Service (RDS) for the content. These items are what are contained in the downloadable GIFT instance. In addition to the basic instances, however, are services for monitoring GIFT; PiWik monitors user behaviors within the system, while the GIFT monitoring service monitors usage for future performance improvements. GIFT now includes an instance to a Social Media Framework (SMF) and Learner Record Store (LRS), which are based around Elgg and Learning Locker, respectively. GIFT's copies of these configurable items are available upon request, and posted to github, but the authors would urge users to select their own instances of commercial sharing and data warehousing items dependent upon their own individual needs; there is nothing tying GIFT to a specific SMF, LRS, PiWik, or monitoring framework. We do not think of these items as core to GIFT, only that they are reported outwards.

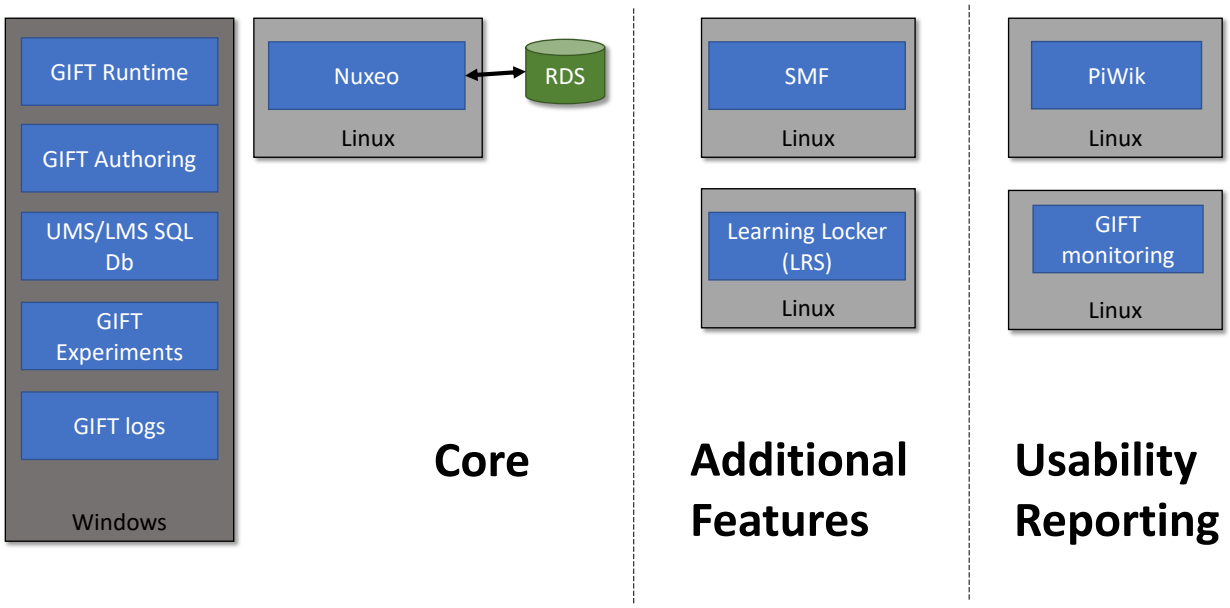

Figure 1: Simplistic Diagram of Cloud Gift Items

NEW INSTRUCTIONAL MODELS

GIFT has historically been based on the Engine for Management of Adaptive Pedagogy (EMAP) processes. These processes were based upon an extensive literature review which diagnosed the best types of content to give learners, based on the traits of the content and learner. This framework has expanded to accommodate Chi's interactive, Constructive, Active, and Passive (iCAP) framework (Chi, 2009; Rowe et al., 2017).

Within the authoring tools, this expansion involves the addition of the "remediation" area to the existing the Rules, Example, Recall, and Practice areas of the Adaptive Courseflow object. Content from this remediation area, if require, is then given preferentially to content in the other areas. If no remediation content is available, or all of the remediation content has already been given, the system will then give a single piece of content from the content within the other bins. This is a change to the behavior of the GIFT adaptive Courseflow object in two manners:

1. Remediation content will be considered before other content when presenting remedial content.

2. Regardless of student performance, only one piece of content will be given prior to retesting

Existing courses are being automatically upgraded in order to use this instructional model, and two instructional events have been added with the ability to be authored within the remediation content block as active/constructive activities – highlight passage and summarize passage. The seamless migration from one instructional model to another instructional model is one of the features of the GIFT system, was designed from the beginning, and is now put to the test.

The move to this instructional model is based upon evidence of effectiveness and is being done in order to support machine learning processes for the optimal selection of remedial content based upon the evidence of effectiveness within an individual course (observed effectiveness) as opposed to effectiveness based upon research projects (theorized effectiveness). More about this project, its results, and the machine learning processes which are being used can be found in (B. S. Goldberg, 2018).

VIRTUAL HUMAN TOOLKIT (VHTK)

There are many problems with the "talking head" process which GIFT has used since the beginning of the project. Firstly, we used this talking head for relatively simplistic reasons – it was already being used as part of the AutoTutor integration and using it by default limited integration cost. Secondly, the character usage was not an open source item, as opposed to the rest of GIFT. Changing the avatar, voice, or character responses usually involved paying Media Semantics a fee. Thirdly, the Media Semantics Character Server and Builder were required to run on Windows, which is also not open source or free. Fourth, Media Semantics has discontinued support of the avatar for modern browser compatibility standards. In summary, it costs money, costs OS maintenance, limits new user adoption, and isn't supported by the company which created it.

For the reasons above, we have wished to switch to another virtual human technology. Previous efforts in allowing GIFT to be more ontology-driven (Nye, Auerbach, Mehta, Hartholt, & Fast, 2017) have allowed for us to use interchangeable agents, and were demonstrated at the last GIFT Symposium. The lack of developmental support for the MSC forced our hand to switch to the new ontology-driven agent processes.

The Virtual Human Toolkit (VHTk) is a collection of modules, tools, and libraries designed to aid and support researchers and developers with the creation of virtual human conversational characters (Hartholt et al., 2013). It provides a way for users to generate virtual humans and integrate them across many projects. Experiments have been performed to assess the ease of the creation of agents, with outputs driving tool design. VHTk is now available open source, and the characters that GIFT will use in the future are VHTk-based, with a VHTk-based agent planned to be available upon the cloud before the publication of this work.

LEARNING TOOLS INTEROPERABILITY

In previously publication, GIFT supported one part of a full LTI connection (Aleven et al., 2017; Brawner et al., 2017). This functional enabled GIFT to be part of an EdX course, or any other LTI Consumer. A GIFT course was run as part of an EdX course, through the LTI interface. EdX passed control of the module to GIFT, students took the GIFT course, and control was passed back to EdX. This flow of connection makes GIFT an "LTI Provider."

GIFT is now also an LTI Consumer, meaning that it can serve the same role as EdX did for GIFT – control during a GIFT course can be relinquished to an external training application, such a Cognitive Tutor exercise, and then returned back to GIFT with score reporting, which can be used elsewhere in the GIFT course per configurable assessment shown within Figure 2. This information can then be used later in the course.

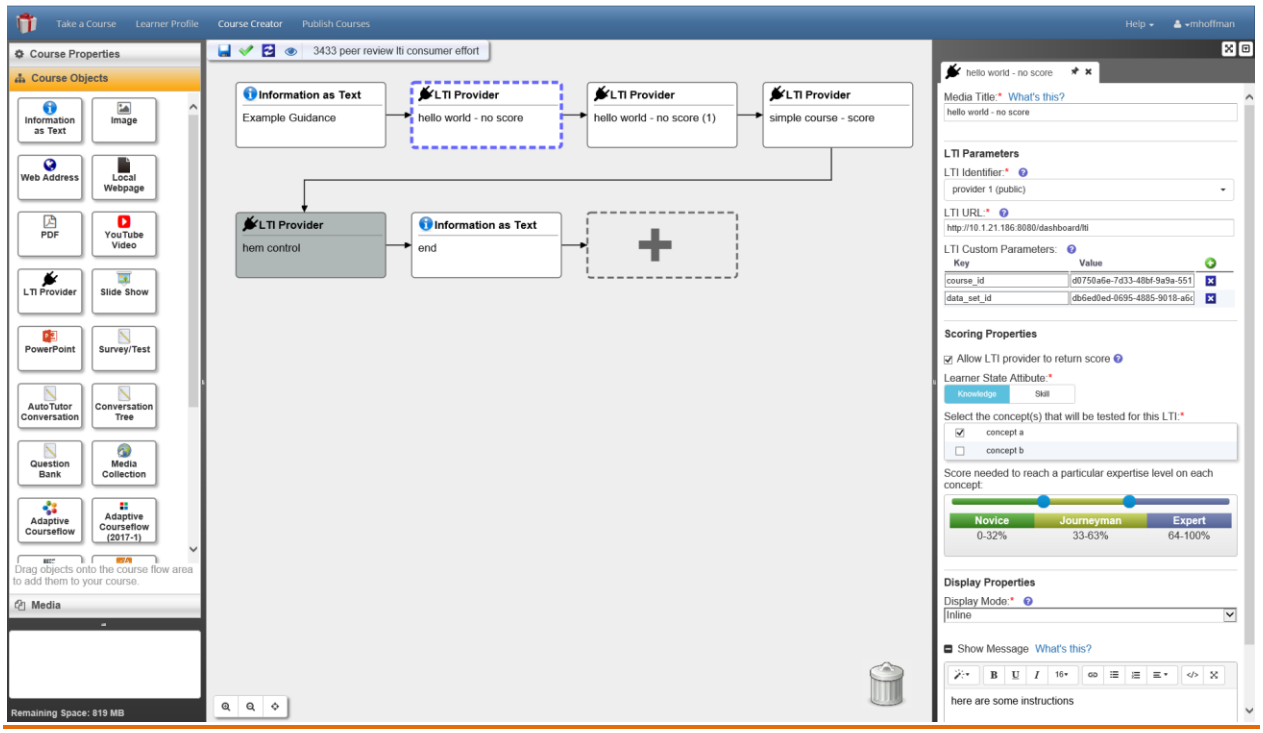

Figure 2: LTI handoff interface

LEARNER RECORD STORE

For a number of years GIFT has supported the functionality of reporting data to a Learner Record Store (LRS) in a configurable xml file. By default, this redirected to a publicly accessible LRS. At the time of writing, Figure 1 shows the connection of GIFT to a hosted LRS, which is now in active use in Cloud GIFT. A sample of the authoring and user interface settings for GIFT is shown in Figure 3. The coming developmental cycle will see the use of LRS data for filtering courses and for pulling learner information for future courses; creating an overarching learner profile used in many places. LRS data is planned to be able to be used across a wide variety of other systems from other Governmental agencies, such as within the Competency and Skills System (CASS).

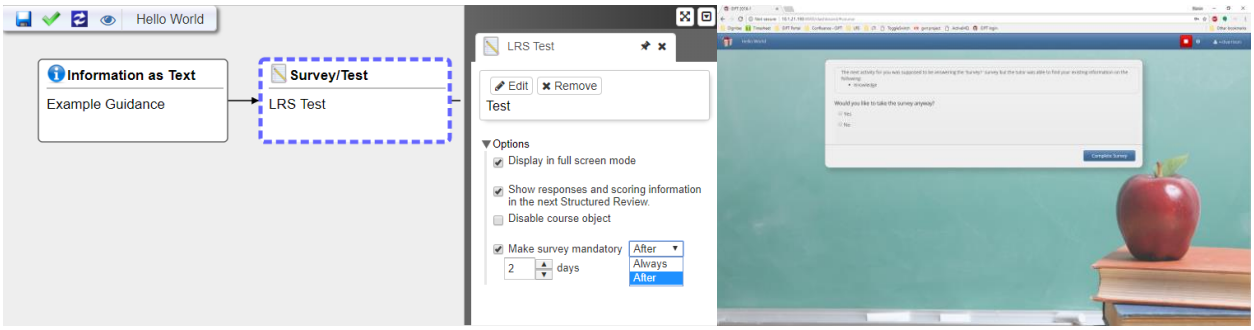

Figure 3: LRS Survey configuration and user experience

AUTHORING

The previous GIFT Symposium put forth the idea of creating a GIFT Course Wizard, which walks a novice author through the process of creating a course, eventually leading them to a created course on the existing course creator page (Murray, Pico, Redmon, & Rowan, 2017). This process has not been implemented, but efforts have been made to streamline the authoring tools, and to help novice authors with the creation of the Quick Start Guide (Ososky, 2016) and the GIFT YouTube video series mentioned earlier.

The most challenging area of authoring remains to be the authoring of the assessment logic which occurs within simulations. In the public example GIFT courses, the reader can see assessment logic configurations for the following, with the following:

- PowerPoint courses
    - over/under-dwell assessments
- Unity simulations
    - Assessment based on button-click events
- Medical training scenarios
    - many domain-specific assessments, such as time to apply tourniquet
    - Assessment is handled with external assessment engine called SIMILE (Mall & Goldberg, 2014)
- Excavator training scenarios
    - Assessment based on movement of the machine
- VBS training scenarios
    - Assessment based on learner movements and actions

The overwhelming challenge is how to support authoring of this diverse set of assessments, without requiring coding knowledge, in a manner independent of the simulation, preferably while authoring simulation

scenarios. Further, this functionality should be available for domain experts who are not experts in instruction, simulations, or GIFT.

Technically, what this authoring tool authors is a Domain Knowledge File, which contains a hierarchal task breakdown of the domain in the form of tasks, conditions, and standards. In the authoring tool, at the time of writing, this is called a "Real Time Assessment" and is authored as a series of Tasks, Concepts and Conditions. A project for building this capability has been ongoing and the functionality that is has developed is reported elsewhere within these proceedings (F. Davis, Riley, & Goldberg, 2018) , as requested and needed in the previous GIFTSym proceedings (F. C. Davis, Riley, & Goldberg, 2017; Ososky, 2017). The functionality of the new tool is anticipated to be deployed in the upcoming GIFT release.

UPCOMING RESEARCH DIRECTIONS: TEAM AND PSYCHOMOTOR TRAINING

Part of the goal of the GIFT project is to expand tutoring systems from relatively well-defined domains to ill-defined domains, from desktop training to "in the wild" training, and from individual training to team training. This is part of the military interest in intelligent tutoring technologies – Warfighters train as a group, and within the training environment.

Team Training

In the realm of team training, the GIFT project has recently finished a project reviewing the literature for what works with team instruction (RA Sottilare et al., 2017). Further, a number of small studies of teams were completed by the team at Iowa State University (Gilbert et al., 2017). These research studies were useful for the initial assessment of the team models, although are lacking in a number of manners. As part of these research discoveries, the system is being re-architected in a manner so as to support team "roles", with tutoring being role specific, but not team-member specific. The reasoning behind these decisions can be read within other research papers (Brawner, Sinatra, & Gilbert, 2018). Specific research implementations can be read elsewhere within this proceedings (Sinatra, 2018).

Psychomotor Training

Psychomotor, or "in the wild" training is a significant part of the reason for military investments in the intelligent tutoring technologies. As part of this effort, work within the domain of marksmanship has been well-published (B. Goldberg, Brawner, Amburn, & Westphal, 2014). Since the previous GIFTSym, the GIFT project has put measures in place to support training of tactical breathing (Kim, Sottilare, & Brawner, 2018) and land navigation. It does so through the use of a mobile application which reads and reports sensor data for physical actions or positioning, respectively, reported to the GIFT server. In prototype fashion, this has worked for one experiment, and a second experiment has been scheduled. The GIFT Mobile App is available upon request, but, at the time of writing, has not been fully tested for functionality.

OTHER NEW FUNCTIONALITY

There are a number of other features which have completed their experimental and developmental cycle are a now either scheduled for integration and deployment, as urged in prior GIFTSym publications, or completed. For the sake of completeness, these are included in the below list:

- Copy Course, downloadable in the latest release, deployed to Cloud GIFT

- VBS3 support, downloadable in the latest release
- Unity support, downloadable in the latest release
- Importing surveys from Qualtrics, downloadable in the latest release, deployed to Cloud GIFT
- Microsoft Band support, downloadable in the latest release
- Adaptive After Action Review (Brawner, Carlin, et al., 2018; Carlin, Brawner, Nucci, Kramer, & Oster, 2017; Carlin et al., 2018), scheduled at time of writing

GIFT AND IEEE STANDARDS

As part of this year's GIFT Symposium, there is an associated standards meeting. This standards meeting will be among those which occurred over the course of the year, including telephone calls, in-person meetings, proceedings presentations, and other activities. The IEEE Learning Technologies Standards Committee, with support from the GIFT community and the Government, is now seeking involvement in standardization activities. The GIFT community invites the reader to join the conversation on what data exchange standards for learning technologies might look like in the future – there is now active IEEE community on the subject, to which the GIFT project is contributing meaningfully. Interested readers are encouraged to go to www.instructionalsciences.org or the IEEE LTSC meetings to become involved.

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Michael Hoffman *is a senior software engineer at Dignitas Technologies and the technical lead for the GIFT project. He has been responsible for ensuring that the development of GIFT, meeting community requirements, and supporting production ITS systems, ITS research, and the growing user community. Michael manages and contributes support for the GIFT community through various mediums including the GIFT portal (www.GIFTTutoring.org), annual GIFT Symposium conferences and technical exchanges with ARL and their contractors. In addition he utilizes his expertise in integrating third party capabilities such as software and hardware systems to enable other organizations to integrate GIFT into their training solutions.*