Development of an Integrated, User-Friendly Authoring Tool for Intelligent Tutoring Systems

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INTRODUCTION

The Generalized Intelligent Framework for Tutoring (GIFT) is a modular suite of capabilities aimed at overcoming the challenges associated with authoring and delivering computer-based instruction via an intelligent tutoring system (Sottilare, Brawner, Goldberg, & Holden, 2012). One of the goals for GIFT development is to create an integrated, user-friendly authoring experience that can be used across training applications. Humanproof, with teammate Design Interactive, is currently developing the second generation GIFT Wrap prototype, a software application that allows training developers to configure the real-time, automated delivery of instructional content triggered by assessing state changes within the training application's learning environment (e.g., entity location within a virtual environment) and/or learner (e.g., progress toward concept mastery, changes in cognitive workload). This ongoing research and development effort is focused on the design and implementation of the user interface that guides users through the set-up of tutoring events. Integration with ARES (Augmented REality Sandtable) served as the first use case. ARES, which can be used as a tactical training and mission rehearsal platform, provided the context for demonstrating GIFT Wrap's utility for defining real-time assessments directly within existing training scenarios. The following sections briefly describe the previous version of GIFT Wrap, provide a detailed discussion of development efforts to date, and present concepts for extending the capability to other training applications as well as live training environments.

GIFT AUTHORING CHALLENGES

Domain Knowledge File

During the completion of a practice event within a GIFT-integrated training application, the GIFT Domain Module accesses the Domain Knowledge File (DKF) configured for that scenario. The DKF contains all of the scenario information, an ontological representation of the concepts being trained in that scenario, and parameters associated with real-time performance assessment of those concepts for pedagogical purposes. The assessment is founded upon relationships between Concepts and Tasks, which are actions completed in learning a concept. During training, the knowledge and skills of a trainee on a given Concept are evaluated using underlying Condition Classes, the rules defining how performance is scored based on available interaction data. GIFT currently uses a DKF Authoring Tool (DAT) which provides a structured, hierarchical view of Concepts and Tasks. Essentially the DAT presents to the training developer a visualization of the eXtensible Markup Language (XML) tree which houses the XML input required to execute the assessment. While users can use an XML editor to create a DKF, the DAT is designed to guide users through the creation of a DKF with the intent of ensuring the training developer creates a DKF that meets required validation criteria.

The DAT was conceptualized and created to support developers in flexibly creating adaptive training; that is, to easily support the creation of real-time assessments for a number of integrated training applications. However, the many intricacies of the system have proven too complex for the average user. For example, depending upon the complexity of the concepts and the depth of the nested hierarchy of Concepts and Tasks, establishing real-time assessments with the DAT may become difficult. This may be compounded

when any number of strategies could be implemented to invoke the start of a real-time assessment or be executed following the comparison of user performance to assessment criteria. The interrelationships make comprehending the structure of the DKF and the resulting real-time assessment challenging. In fact, Shute, Ventura, Small & Goldberg (2013) described the need for users to encode conditions and instructional strategies in a DKF for real-time assessment, and highlighted the potential difficulty in understanding the structure and function of the DKF. Given the variety of training applications that can be utilized with the GIFT framework and the variety of ways performance can be assessed, users often need a high degree of skill to correctly encode Condition Classes and Strategies for the real-time assessment, as well as to create a DKF that is valid for use within the selected training application. Furthermore, as GIFT matures, more training applications may be integrated into the framework, leading to the need for substantially different conditions for performance assessment than are currently present. Currently Condition Classes are created for specific tasks via custom Java classes in the source code that are referenced by the DKF XML. GIFT currently presents any number of Condition Classes to users during the set-up of a course, but only a few may relate to the training application actually being used. If a Condition Class that is needed is not available, one must be created by building the appropriate Java classes in the source code and recompiling before building the DKF. The current DAT interface can be improved to better support users in DKF development and expand capabilities for configuring Condition Classes given functional capabilities and underlying data structures of existing and emerging GIFT training applications.

Disconnect between GIFT and Training Applications

In addition to the difficulty in creating a DKF in absence of key XML technical skills and creation of new Condition Classes for training applications, the current GIFT user must work within the GIFT course authoring application as well as any scenario or course authoring module of the selected training application to set up a course. Currently, while communication "gateways" exist between GIFT and various training applications, there is no real-time communication between the entities during the set-up of scenarios and the associated real-time assessments. As such, users must complete some set-up tasks with GIFT and then independently set-up other aspects of the scenario and or training via the training application. Currently, very limited interface support or direct integration exists that would allow a user to author a DKF while simultaneously (without cumbersome toggling) accessing or retrieving necessary data from the training application to set up task parameters, scoring conditions, or instructional strategies. Work toward supporting seamless integration for the set-up of GIFT courses would improve upon the user experience and perhaps speed up the course development process while reducing human error associated with complicated authoring functions.

AUTHORING WITH GIFT WRAP

First Generation

As previously discussed in this paper, one of the barriers to authoring in GIFT is configuring the DKF to create a set of assessments and instructional strategies for use with a particular training application. The first generation of GIFT Wrap addressed this challenge by providing capabilities for training developers to author tutoring content while simultaneously interacting with a training application's content creation tools (Hoffman, Markuck, & Goldberg, 2014). This first generation of GIFT Wrap was designed for integration with the ARES training application and provided training developers with the ability to create survey assessments of comprehension (i.e., a check on learning (COL)) including selecting specific survey response options directly from the content creation interface used by the training application (i.e., ARES terrain map). GIFT Wrap effectively provided a user-friendly tool for creating COL items and eliminated the disconnect between the two applications via its blended authoring environment (see Figure

1). This improved design significantly reduced the challenges associated with creating survey assessments that referenced scenario objects within a given training application. However, this first generation of GIFT Wrap functionality was limited to the COL. A substantial amount of additional tools and interface enhancements were needed to provide a solution encompassing the entire breadth of the ever increasing DKF functionality.
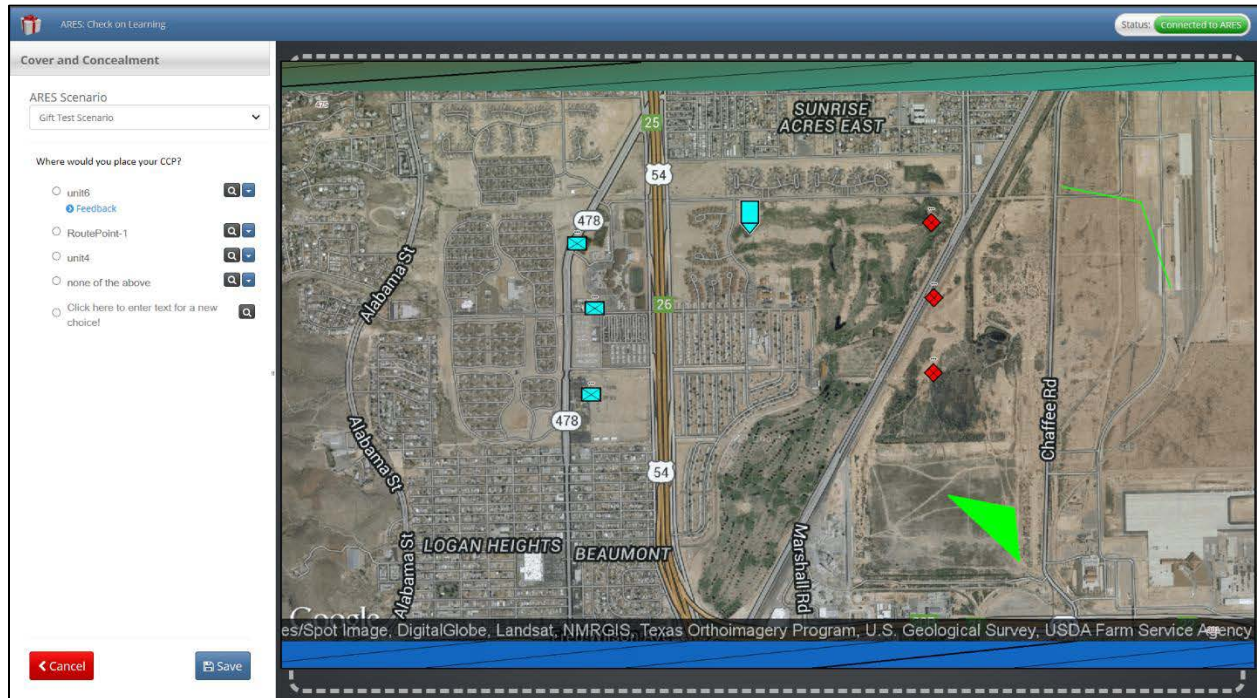

Figure 1. GIFT Wrap authoring experience showing a blended authoring environment with COL creation (left) and training application content creation (right).

Second Generation

Currently under development, the second generation of GIFT Wrap functionality aims to build upon the existing GIFT Wrap functionality by (1) providing a user-friendly tool for creating, configuring, and managing a DKF, including support for existing and future real-time assessments, and (2) further reducing the disconnect between authoring in GIFT and authoring within a training application's content creation environment. The following sections describe each of these efforts in greater detail.

User-friendly Authoring Interface

As previously stated, users often need a high degree of skill to create a DKF that is valid for use within the selected training application. The second generation of GIFT Wrap seeks to address the technical skills gap by providing an intuitive user interface (UI) for authoring a custom DKF. First, the organization of Tasks and Concepts has been restructured into a tree-like menu (see Figure 2) of "Tutoring Events". This menu is always visible to the user allowing them to view the entire set of Tasks and Concepts at their preferred level of detail by collapsing or expanding the menu for each Task. Furthermore, the menu is purposely designed to guide the user through each step including creating a Task and then configuring the Start Trigger, set of Concepts, and finally the End Trigger. Feedback on the user's progress is provided in the form of checkmarks indicating whether or not a particular step in the process has been completed.
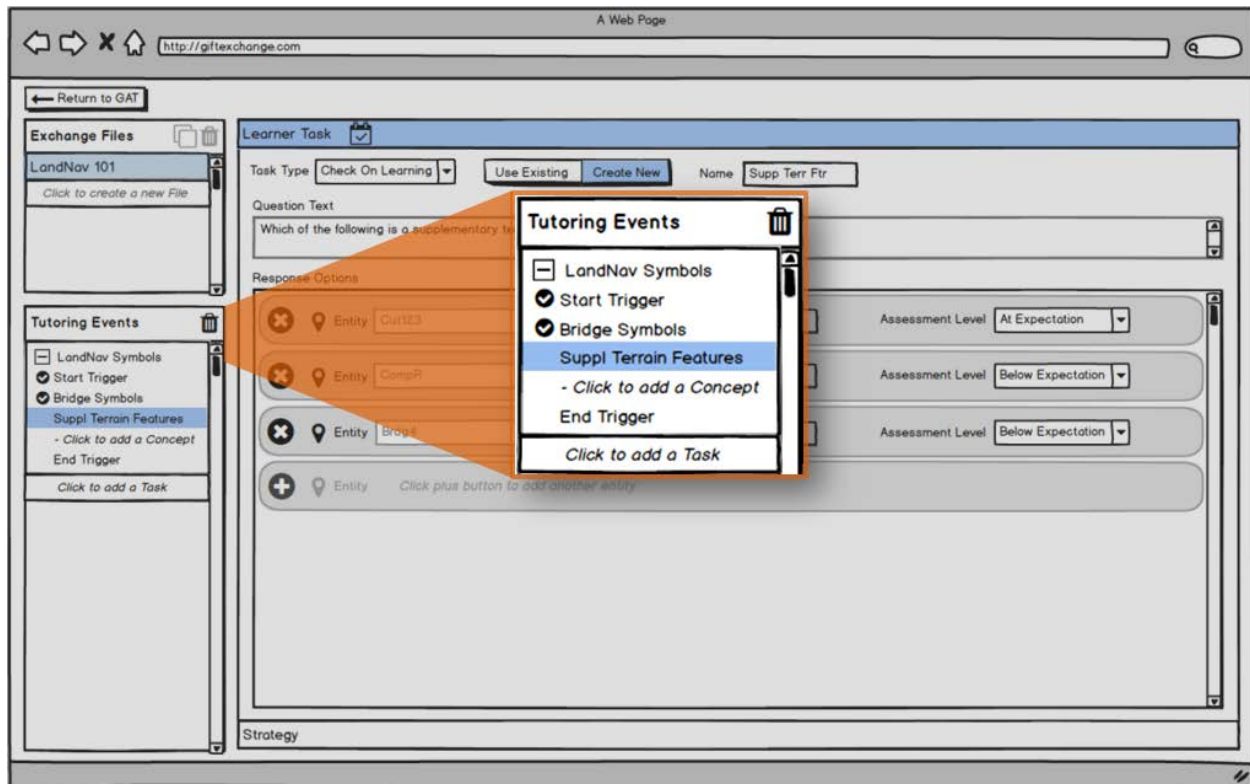
Figure 2. Tutoring Events menu guiding the user through creating a Task, configuring the Start Trigger, creating a set of Concepts, and configuring the End Trigger.

Consider the following example of how a user would interact with the Tutoring Events menu. A training developer is authoring a course on land navigation. As part of the course, the training developer would like the learner to be assessed on their mastery of map symbology using the ARES training application. Specifically, the training developer will require the learner to complete an activity that involves responding to a COL that requires them to identify two supplementary terrain features. Proceeding through each step presented by the Tutoring Events menu, they would first add and name a task "LandNav" symbols. Next, the training developer would configure a Start Trigger. In this case, they select a Timer trigger set to go off five minutes after the ARES scenario is presented. Next, the training developer would add a Concept and name it "Supplementary Terrain Features". This Concept will be assessed using a COL. After configuring the COL including the query text (i.e., Please identify two supplementary terrain features.) and response options (e.g., cut icon, fill icon), the training developer would configure an End Trigger. In this case, they select a Concept Ended trigger that will be activated once the learner completes the COL. The process is now complete unless the Training Developer would like to add additional Tasks and Concepts. While this menu is designed to support a linear process flow such as the one described in this example, it is also intended to be flexible enough to avoid hindering more advanced users.

Second, GIFT Wrap provides a redesigned interface for configuring real-time assessments and Strategies for each Concept (see Figure 3). Real-time assessments are now framed as "Learner Tasks" or activities that a learner must complete during interaction with the training application for the purpose of evaluating their mastery of a particular Concept or one of its components. Within the GIFT Wrap, each Condition Class will have its own custom-designed UI elements based on the assessment schema defined in the source code. It is also worth noting that only those Condition Classes compatible with a specific training application will be made available to the user during the authoring workflow, as it will enable a developer

to understand the types of tasks and interactions they can configure their concept assessments around. For example, a new Condition Class known as a "Layout Task" has been developed specifically for use with ARES and other similar terrain associated related training applications. The Layout Task is designed to assess the degree to which a learner can place icons in the correct location on a presented two-dimensional space. In the current generation of GIFT Wrap, the task involves learners placing map icons in the correct location on an ARES presented terrain map. Again, in an effort to improve usability, the GIFT Wrap user is provided with an intuitive UI for authoring the query regarding positioning map symbology on the terrain, selecting the correct position of each element and corresponding tolerance for error, and configuring the assessment logic for each potential response from the learner. GIFT Wrap then translates the user's selections into inputs for the associated XML schema, automatically creating the DKF, in a manner that is transparent to the user.

No programming skills are required to configure the Learner Task and/or other Condition Classes available in the current generation of GIFT Wrap. Additionally, where possible, common UI elements are used for similar types of Condition Classes. For example, the COL Learner Task, which also requires the learner to select icons from the ARES terrain map, uses an almost identical UI and follows a similar process. Standardizing the UI across related or common functionality increases the usability of the tool by allowing users to quickly recognize and operate familiar functionality they've already learned to use.
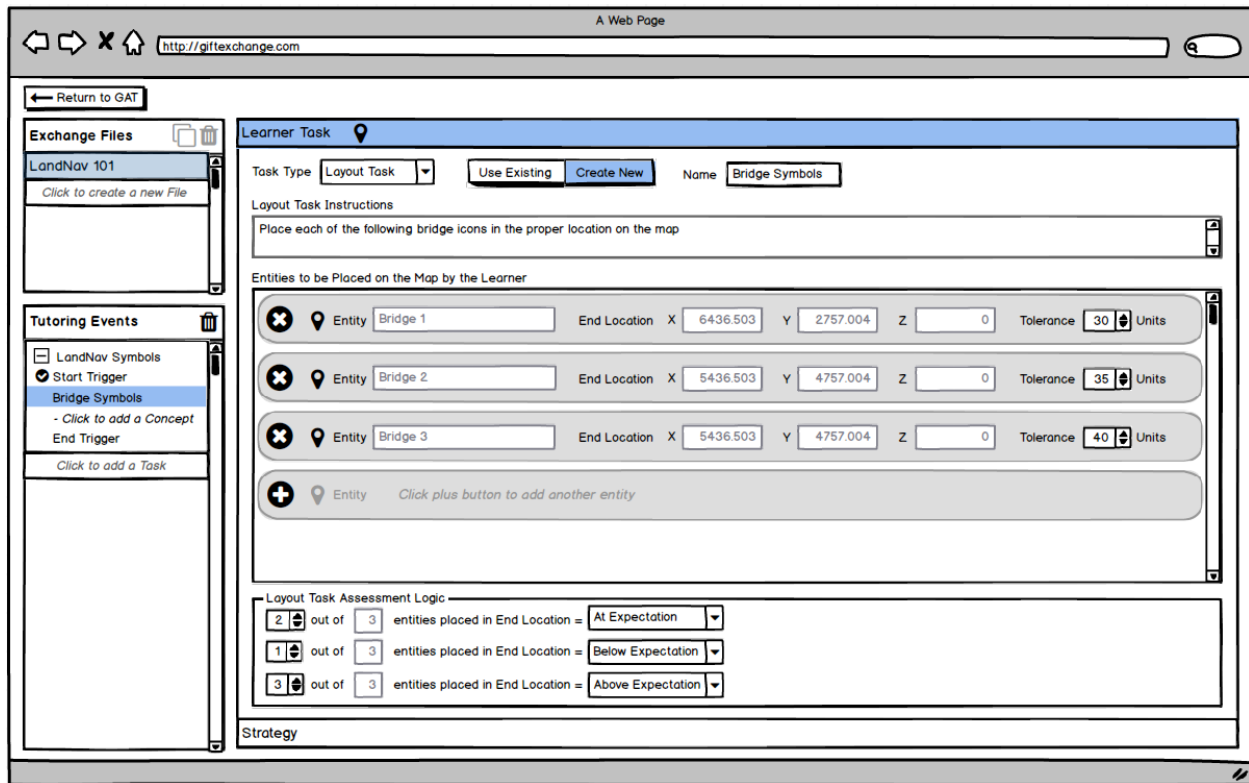

Figure 3. Flexible UI for configuring Condition Classes (Learner Tasks) and Strategies.

While the current generation of GIFT Wrap focuses on real-time assessments, including their underlying Condition Classes, relevant to ARES, future iterations of the tool will be developed that continue to incorporate the many available Condition Classes used by a DKF into the user-friendly Learner Task UI provided by GIFT Wrap. As other training applications and environments (e.g., interactive gaming environments) are explored, efforts will be made to identify new kinds of assessments, prioritize the most

useful functionality for development, and to standardize functionality where possible to maintain a user-centered approach to authoring tool development.

Blended Authoring Environments

As previously stated, the first generation of GIFT Wrap established a blended authoring environment for creating COL survey assessments alongside the ARES content creation tool all within the confines of a single screen. The second generation of GIFT Wrap seeks to further overcome the disconnect between the GIFT authoring environment, in this case the DAT, and a training application's content creation tools by (1) further integrating GIFT Wrap functionality with that of the training application and (2) creating additional UI components to support the configuration of additional Condition Classes.

GIFT Wrap – Training Application Integration

In addition to COLs, GIFT Wrap now provides users with the ability to add response options for the Layout Task query by selecting map icons directly from the ARES scenario editor (see Figure 4). As demonstrated by the first generation of GIFT Wrap, this direct integration between GIFT Wrap and the training application eliminates the requirement for users to constantly toggle between the GIFT Wrap and ARES, manually entering entity IDs one-by-one. This reduces the time required to author assessments that require the user to reference an entity ID (e.g., COL, Layout Task) and decreases the likelihood for entry and selection errors thereby enhancing the usability of the tool. Furthermore, rather than being presented as a separate set of functionality from that of the DAT, the capability to create real-time assessments, such as the COL and Layout Task, is now part of the second generation GIFT Wrap inter-face allowing for the creation of Tasks, Concepts, real-time assessments, and Strategies all in one place.
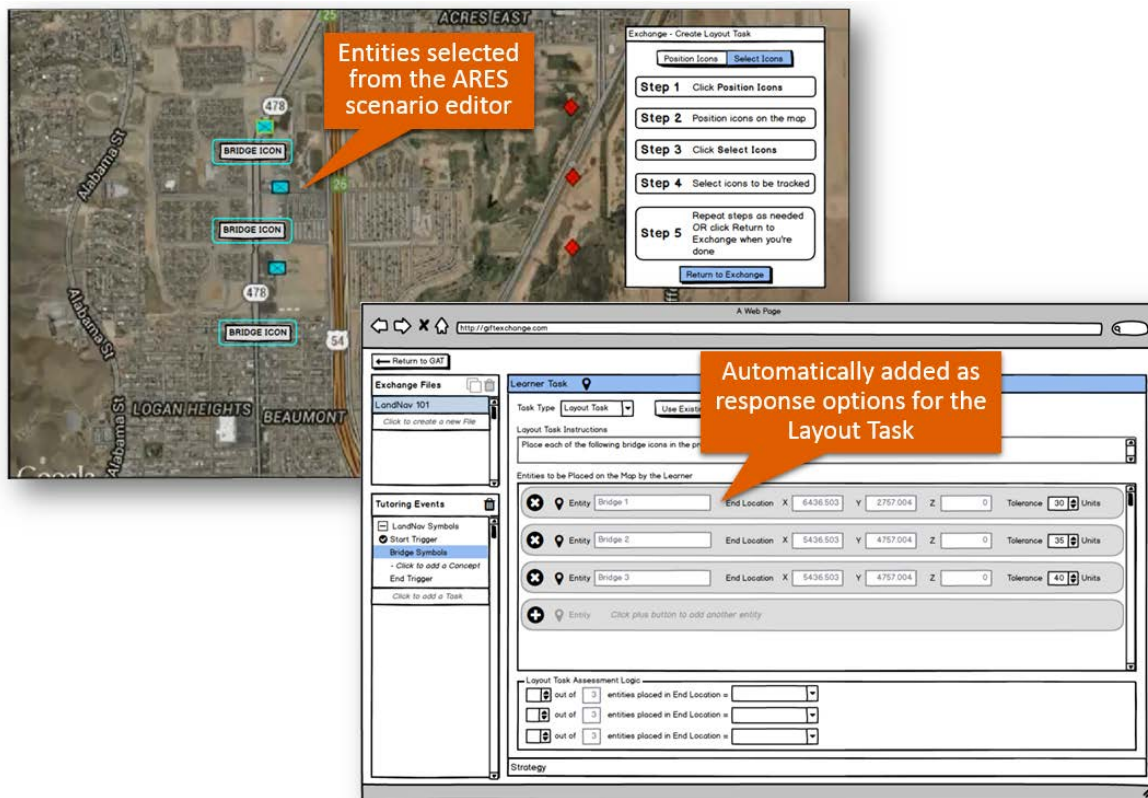

Figure 4. GIFT Wrap – Training Application Integration in support of a blended authoring experience.

Overlay UI

The first generation of GIFT Wrap presented the COL authoring UI directly alongside the ARES scenario editor within the same page (see Figure 1). While this was designed to support a one-screen solution, the GIFT Wrap UI expended a significant portion of the overall screen real estate available. In an effort to retain the one-screen design, create a framework that would support authoring additional Condition Classes, and improve the overall usability of the tool, an "overlay" UI was developed (see Figure 5). This new design includes the following benefits and features:

- The overlay is designed to be distinct from the background (i.e., a training application's content creation tools), in an effort to avoid confusion between the two environments.
- The overlay is presented on top of the underlying screen and may be repositioned as to not obscure or block access to content. It also avoids distortion or reduction of screen estate available for the training application's content creation tools.
- In an effort to guide the users through each step of authoring the Condition Class, the overlay is designed to provide a simple, visual guide (i.e., numbered steps) through the required sequence of actions. The design also allows the user to pause work with the Condition Class and easily switch to editing the training application's configuration (e.g., adjusting the location of icons on the ARES terrain map).
- The overlay presents only a sub-set of functionality (i.e., selecting icons) required to configure the Condition Class rather than all of the associated settings (e.g., query text, assessment logic) reducing the size requirement of the overlay and use of valuable screen space.
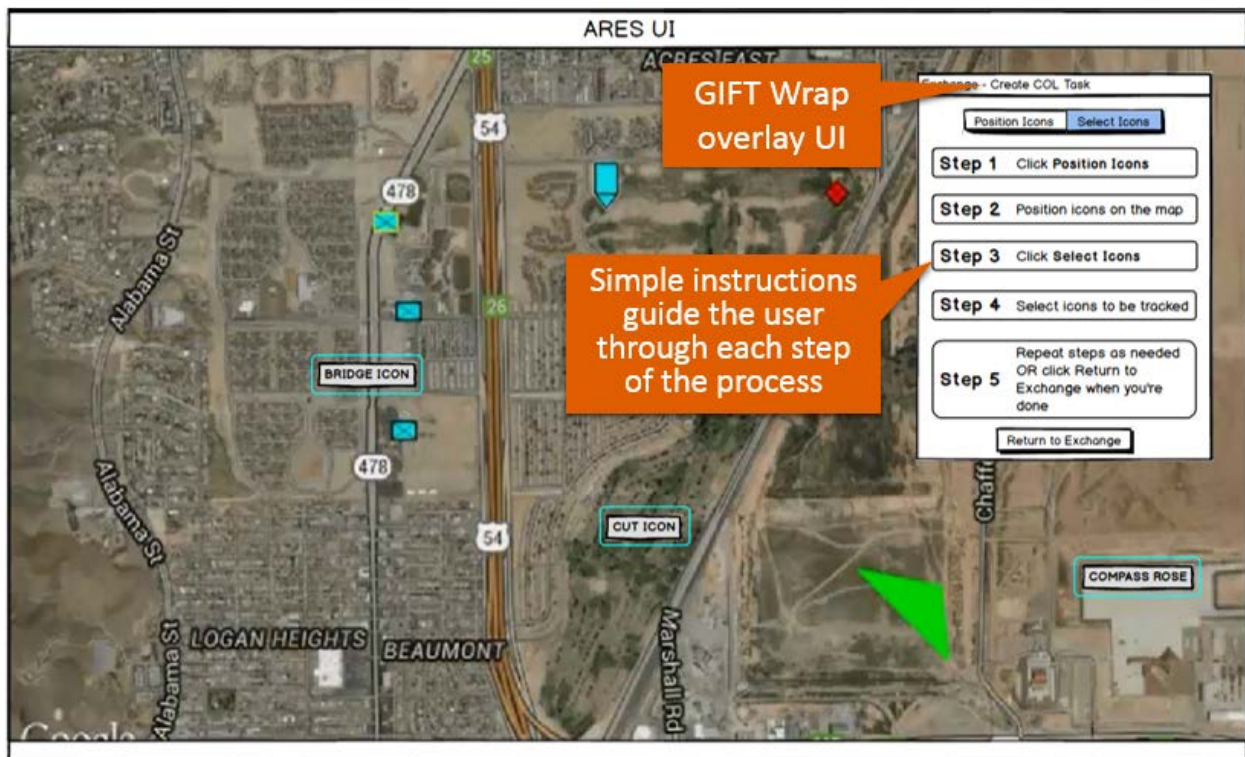

Figure 5. GIFT Wrap overlay UI supporting an enhanced, blended authoring experience.

Currently, the overlay design effectively supports configuring both the COL and Layout Task. Users can quickly alternate, or toggle, between interactions with the overlay and the ARES interface. In the near-term development of GIFT Wrap, it will be easily expandable to accommodate other map-based assess-

ments associated with training applications such as Virtual Battlespace (VBS). In these instances, the assessment logic configured in GIFT Wrap will incorporate new data elements that will increase the complexity of measures configured in a DKF. These elements include interactions captured in first-person shooter type training applications where users control avatars in a virtual environment, and interact with scenario-based objects for the purpose of meeting task objectives. The movements and interactions across all entities and objects must be mapped for performing assessment type practices for tracking progress and identifying task deficiencies.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Building on the first generation of GIFT Wrap, the second generation prototype successfully added a new suite of functionality and enhanced many existing features. The new GIFT Wrap UI facilitates the development of DKFs that drive real-time assessments in a guided, step-through fashion. The interface requires no programming skills (e.g., Java programming, XML familiarity) to develop a valid DKF, with associated Condition Classes and Strategies. Next, the second generation of GIFT Wrap enhanced the blended authoring experience by supporting additional capabilities, such as the Layout Task, and by providing a user-friendly overlay UI easily extendible to authoring other map-based assessments.

While the second generation of GIFT Wrap was designed to accommodate existing DKF functionality and for use with the ARES training application, the overall framework of the tool was developed with an eye toward accommodating a wide variety of future Intelligent Tutoring Systems (ITS) functionality and other training applications. In the immediate future, GIFT Wrap research and development efforts will focus on incorporating additional DKF functionality, such as new Condition Classes (e.g., follow route) and Strategies (e.g., , survey assessments), and integration with VBS. This effort will require developing new features aimed at improving and streamlining the user experience associated with creating a DKF via the GIFT Wrap UI. It will also require investigating the potential assessments that are possible to implement within VBS, identifying those most useful to training developers, and prioritizing them for implementation. These findings will guide the expansion of GIFT Wrap authoring capabilities that incorporate these additional assessments including the corresponding UI features that promote an increasingly blended authoring environment.

Following near term research and development efforts, the focus will shift toward extending GIFT-delivered training into real-world environments. Authoring within a training application's content creation tools will be replaced with authoring within representations of real-world spaces via integration with technology such as Google Maps. For example, rather than the GIFT Wrap overlay UI being presented on top of a training application's content creation tools (e.g., VBS mission editor), it will be presented on top of a real-world map. This integration with live environments will essentially create a new training application, to which all GIFT Wrap authoring functionality could apply. Inputs driving real-time assessments that were previously captured from the virtual training environment will be replaced with real-world data from trainees participating in live exercises while being monitored using Bluetooth® and other wireless technology. User-interaction with GIFT via computer displays will be replaced by leveraging mobile and augmented reality technology to interface with trainees and provide a mechanism for delivering interventions (e.g., feedback, prompting). Together with existing GIFT capabilities, this new suite of technology will allow training developers to apply many of the same ITS approaches to more traditional training environments and provide support for Army trainees as they progress from the classroom environment all the way into the field.

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