

Authoring Augmented Reality Scenarios for Intelligent Tutoring Systems with GIFT

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INTRODUCTION

Developments in see-through displays combined with multi-modal interaction techniques (Renambot, et al., 2014) have revealed rich possibilities in the realms of tutoring and training. The use of depth cameras, precise tracking devices and vision algorithms allow for a combination of real world environment training with virtual elements. In this paper we explore this domain by examining the interface needed to couple augmented reality (AR) scenarios with an intelligent tutoring system.

We propose a user interface for authoring an augmented reality tutoring course built upon the Generalized Intelligent Framework for Tutoring, known as GIFT (Sottolare, Brawner, Goldberg, & Holden, 2012). This intelligent tutoring framework contains a broad set of tools and algorithms to author tutoring systems that utilize concepts such as Learning Effect Model (Sottolare R. A., 2015) and can be applied to individuals or in teams. GIFT also provides efficient development of intelligent tutoring systems (ITSs) and is backed by a broad set of components in the learner, domain and instructional modeling (Goodwin, et al., 2015; Sottolare, Ososky, & Boyce, 2015; Goldberg, Sottolare, Moss, & Sinatra, 2016). Combined with the tool we developed, the GIFT Augmented Reality Authoring Tool (GARAT), we show a starting point in analyzing and understanding the problems that arise when integrating an intelligent tutoring system with an augmented reality scene.

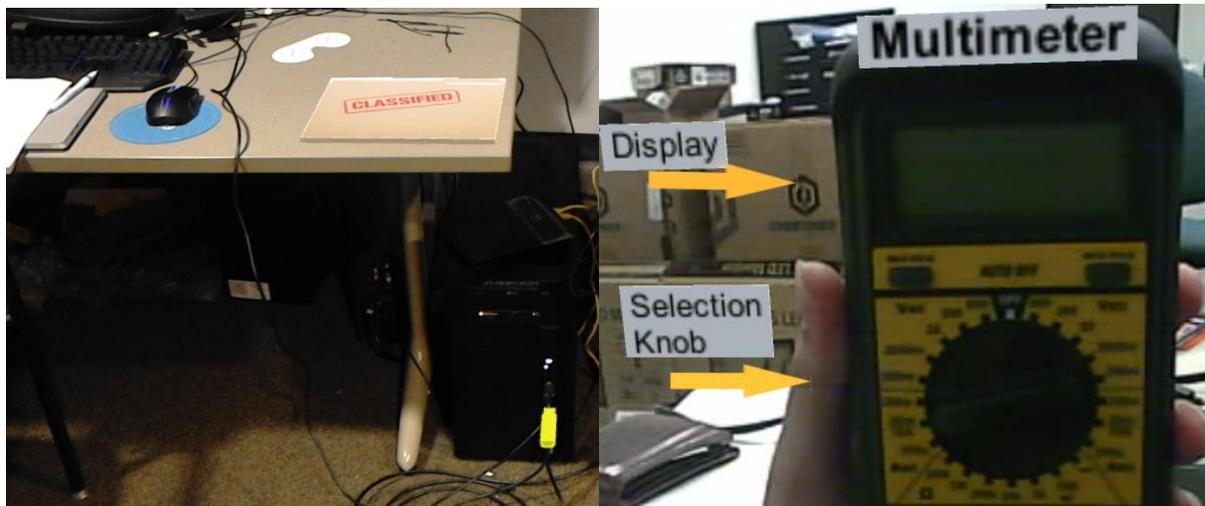


Figure 1. Two example AR courses developed in this paper. The left image shows a training scenario with sensitive information represented by virtual items left unattended. The right image shows training of a multimeter with indicators presented to the user.

We developed the environment that allows to author augmented reality scenarios via GARAT, connect to GIFT via interops and a testbed for the development of tutoring external applications via HoloLens (Statt, 2015). GARAT does not support any other course information authoring but allows to be integrated in the GIFT Authoring Tool pipeline. The GARAT interface works with an external training application running

on the latest commercial off the shelf see-through display, the HoloLens, which is used for both the authoring tool and the display of the augmented reality course. While this device is used as the primary interaction medium, our proposed interface can be extended to any platform. The HoloLens creates a 3D mapping of the real world environment which is represented as a mesh back into the authoring tools. While not highly detailed we demonstrate its ability to provide context in the tutoring course design. When the course is executed, the HoloLens's accurate head tracking is used to anchor virtual objects to the real world.

Two example training applications were developed for this paper, both shown in Figure 1. First, we have the user identify possible information risks within a sensitive compartmented information facility (SCIF). The SCIF itself is simulated with virtual items used to represent the identifiable risks. Thanks to the use of augmented reality the training may take place in any environment without creating a real risk of an information leak. The second application involves requesting information regarding a specific device, a multi-meter, back to the tutor.

The integration of augmented reality and intelligent tutoring is a new domain which we demonstrate a starting point in the authoring of an AR course and the problems that must be overcome in doing so. We also show a potential pipeline for the implementation of augmented reality tutoring experiences through the use of a framework, such as GIFT, and a commercial see-through device, the HoloLens.

In section two of this paper we go through related work in the field. Section three goes into the interface integration with GIFT along with a detailed description of the setup which lead to GARAT. Section four illustrates the detailed usage of our authoring tool along with the creation of the two above training courses. Section five wraps up our research with a discussion of our conclusions and a recommendation for future work.

RELATED WORK

Augmented Reality Scenarios

Lee's SpaceTop (Lee, Olwal, Ishii, & Boulanger, 2013) and Xin's Napkin Sketch (Xin, Sharlin, & Sousa, 2008) provide guidelines for the seamless transition between 2D and 3D interaction; the former is presented as a single hybrid workspace, while the latter is a Mixed-Reality space interacting with a sketch. Pilot studies from both works indicate high user satisfaction with both interfaces, where users found the system quite intuitive and easy to grasp. A participant from SpaceTop, however, experienced arm fatigue during the trials, and overall, SpaceTop is not sufficiently responsive and accurate. Napkin Sketch was found to foster creativity, but users found the system laborious when asked to calibrate their best perspective for sketching. These considerations are important when working with interfaces involving physical load in the case of sketching on 3D. To address these issues our prototype has a real time update and an in-site 2D interface of the scenario being authored.

Authoring AR & Tutoring Systems

Several commercial and academic tools have been proposed to author AR scenarios. (Mota, Roberto, & Teichrieb, 2015) proposes a classification of the different tools and concludes with a taxonomy composed by two authoring paradigms: stand-alone and AR-plugins and two distribution strategies: platform-specific and platform independent. Our prototype falls under the category of AR-plugins because it is an add-on for GIFT and platform independent since GIFT offers capabilities to integrate with any external application. Authoring in immersive scenarios has been widely studied in (Lee, Nelles, Billingham, & Kim, 2004) where they set specific guidelines for authoring tasks and objects behaviors in tangible AR applications.

Different domains have benefitted from AR combined with ITS. For example in the military domain, soldiers require training on physical tasks but the adaptive training techniques are being instructed in a desktop environment (Goldberg B. , Sottolare, Brawner, & Holden, 2012). In order to extend ITS beyond the desktop, a pipeline for the development of a possible training scenario is introduced in (LaViola, et al., 2015). Additionally, an analysis of different smart glasses for tutoring in the wild is presented in (Sottolare & LaViola, 2015). Different factors and trade offs are exposed under different duties such as land navigation, maintenance, tactical planning, etc. The benefits of ITS combined with AR is demonstrated in (Westerfield, 2015), where two groups were trained in a motherboard assembly task. The group that was trained with AR without adaptive instruction underperformed in test scores compared to the group with intelligent support.

INTEGRATION WITH GIFT

GIFT uses service-oriented architecture (SOA) plugins which can be developed to allow external applications to communicate with the framework. In Figure 2 a reduced version of the GIFT functional blocks displays our modified components in red. We implemented a new interop to interface with Unity 3D and a XML Remote Procedure Call (XMLRPC) server and client to communicate GIFT with Windows Universal Platform Applications (HoloLens). The plugin is used when authoring a course in the GIFT Authoring Tool (GAT) and also when a course is started from the Tutor User Interface (TUI). The training application connects via XMLRPC in a seamless exchange of information based on the course assessment definitions just like it does in the examples provided by GIFT.

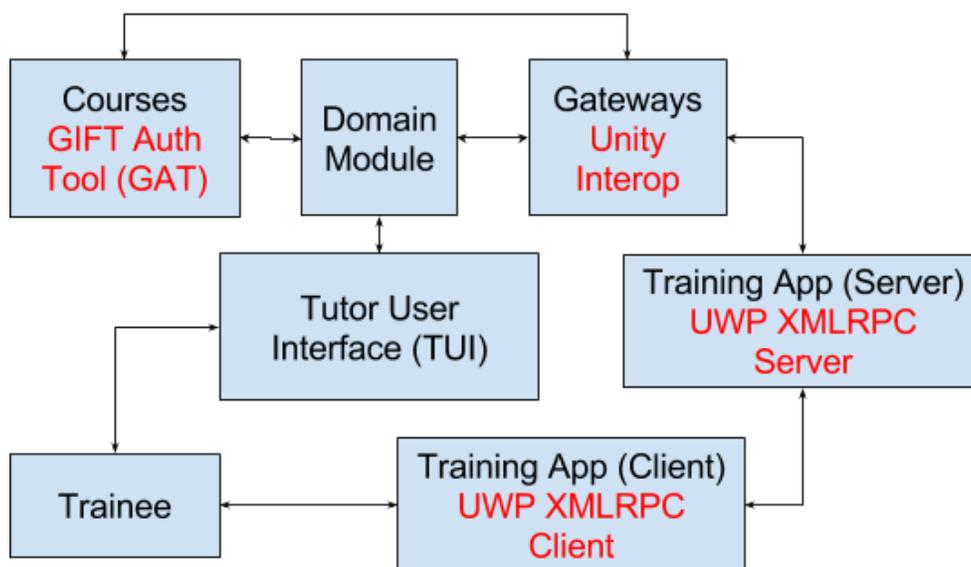


Figure 2. Modifications made to the GIFT functional blocks. Red text denotes additions to expand functionality. Note the new Unity interop option added in the GIFT Authoring Tool as well as an XMLRPC implementation for Universal Windows Platform.

Authoring an AR Scene in the GAT

For the authoring of an Augmented Reality Scenario we introduce a plugin we call the GIFT Augmented Reality Authoring Tool (GARAT) which is an interface to visualize and interact with 3D information. To access the tool an external application from the course objects should be added to the course flow. Inside its attributes are the application type: Unity application will invoke the GARAT plugin. The tool is divided in three sections left, center and right panels. The left panel shows assets located in the GIFT user directory,

its properties and a preview of it. The center panel presents a 3D canvas initially empty which can contain information imported from assets or an external third party application e.g. room mesh. It also provides buttons to apply transformations to the assets, manage the 3D mesh acquisition server, load previously saved mesh, save mesh from the 3D canvas, clear the 3D canvas and generate a color point cloud. The 3D data in the canvas can be visualized as Mesh, Point Cloud and Wireframe via radio buttons on the bottom of the canvas, as shown in Figure 3.

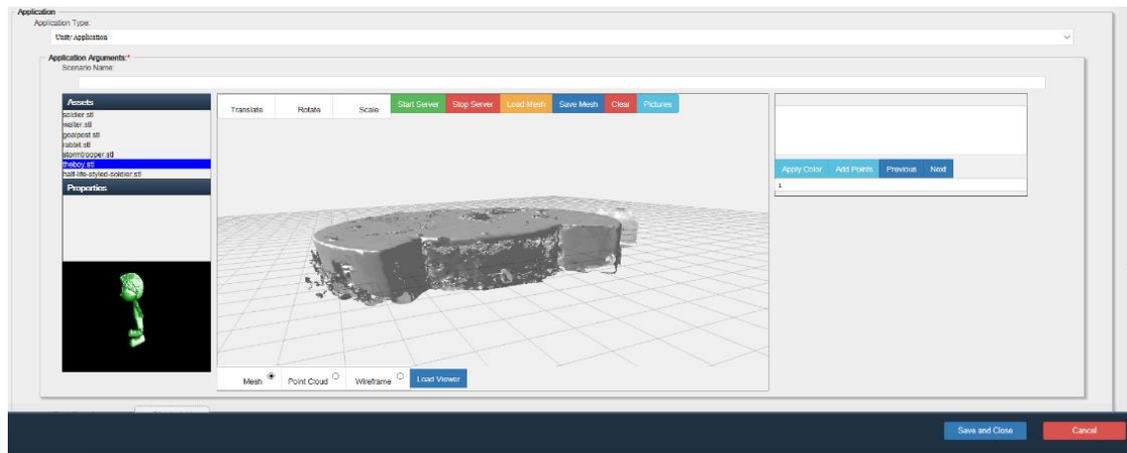


Figure 3. GARAT user interface. The left panel shows a preview of an asset. The central panel shows the mesh of a room as well as the different buttons to interact with.

3D Reconstruction from HoloLens

An important aspect in the authoring of an AR scene is to provide the author a spatial mapping of the physical space. To achieve this a universal windows application for HoloLens is developed. Once installed on the HoloLens, the authoring application can be started from the start menu. There are two modes of interaction: by voice and by gaze-tap. In order to start retrieving the geometry of the room, first from GARAT the plugin needs to be listening by clicking the “Start Server” button. If successful the tool will be ready to receive the data. Next, from the HoloLens application, a 3D map of the environment can be acquired by verbally saying “Start Scan” or “Open Menu”. The “Open Menu” statement will place the menu and allow the user to gaze-tap on the “Scan” button. A wireframe render around the geometry of the physical elements in the room is shown as can be seen in Figure 4. The information being rendered can be sent to GIFT to be displayed in GARAT by saying “Send Mesh” or by saying “Open Menu” followed by a gaze-tap on the “Send” button. It is important as well to attach anchors in the scene by verbally saying “Open Menu” followed by a gaze-tap on “Set Anchors”, then proceed to gaze at an specific point in the room and tap to place the anchor; this is for aligning HoloLens and GARAT 3D canvas coordinate systems when the tutoring application starts.

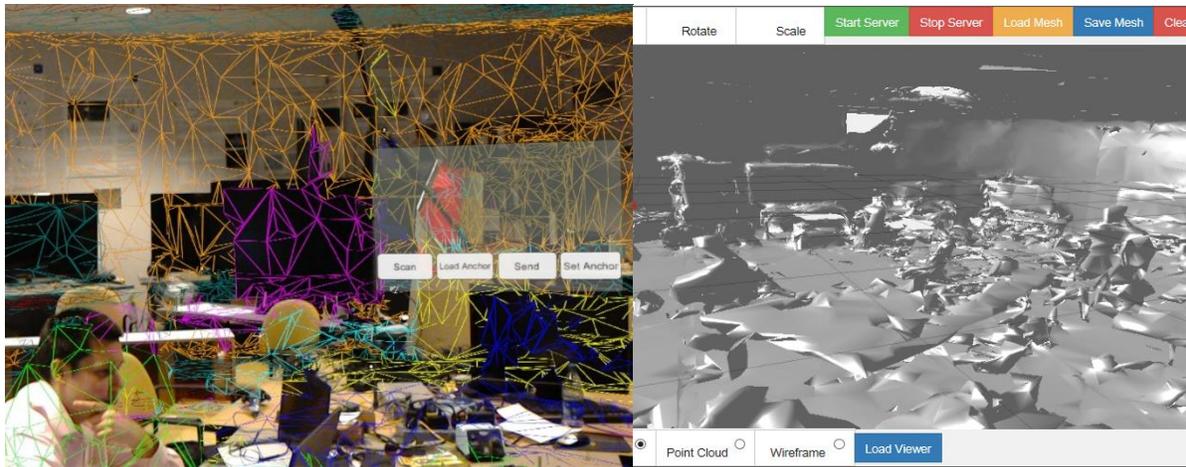


Figure 4. Left image shows the HoloLens application to scan a room with the menu controls open. Right image shows the mesh representation of the scan visualized in the GARAT 3D canvas.

The mesh generated from the reconstruction does not provide color information. In order to mitigate this problem a point cloud is generated from the mesh using rgb information coupled with extrinsic and intrinsic parameters retrieved from the HoloLens front camera. According to Windows Holographics documentation the extrinsic parameters store the camera's pose in the camera coordinate system, on the other hand the intrinsic properties (focal length, center of projection, skew) represent the projection transform mapped onto an image plane that goes from -1 to +1. This information is captured by saying "Take Picture" which will pack the data and upload it to the GIFT server. In the GARAT interface the pictures can be visualized on the right panel and can be traversed by clicking "Next" and "Previous" buttons. The point cloud is generated by first clicking on "Pictures", then selecting the image and finally clicking "Apply Color". As can be seen in Figure 5 a color point cloud was generated from the picture information in the right panel. One disadvantage of this method is that it needs to be repeated by each picture as the HoloLens interface does not allow complete control over the 3D information acquired (rgb, depth and camera parameters) in real time.

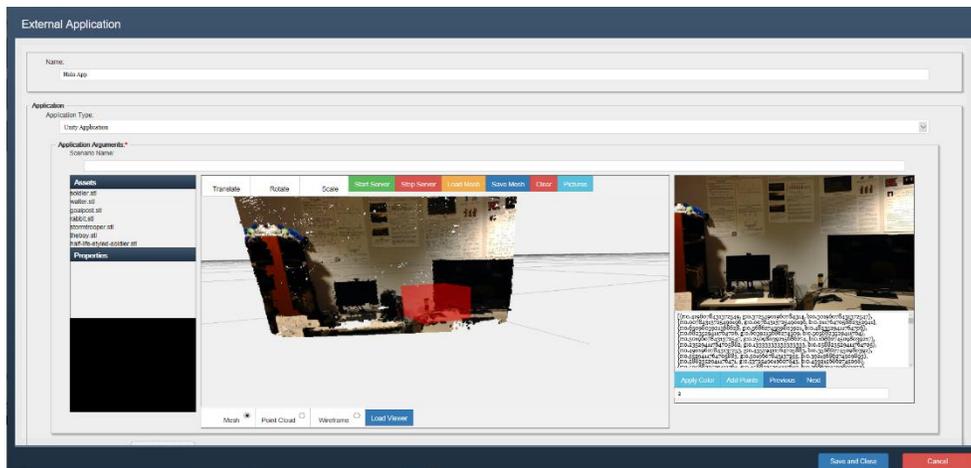


Figure 5. Point Cloud generated from the information in the right panel. The red cube represents the position and orientation of the camera the picture was taken with.

AUTHORING AUGMENTED REALITY ITS

The following section involves content to be learned by a student. Our study focuses on the external application course object that corresponds to the user interface proposed in this paper to author AR scenarios. For the first tutoring system, once a 3D room is loaded in the canvas, from the HoloLens application, anchors should be loaded to align coordinate systems between HoloLens and the GARAT 3D canvas. Next, in the left panel of the GARAT assets can be visualized and added to the scene via drag and drop as can be seen in Figure 6. The camera can be moved via pan, zoom and tilt with mouse or touch interactions. An object can be selected by clicking on it and transformations can be applied to it or information can be set in the properties panel, such as the object's name. In the HoloLens the author can visualize the 3D elements in the GIFT interface as well as in the real world. The course can then be saved and the assets in the HoloLens tutoring application will be loaded based on the name and the transformations applied in GARAT.

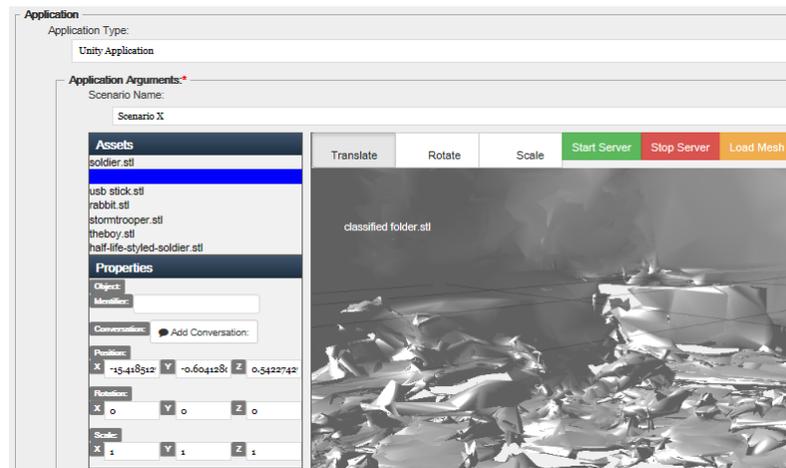


Figure 6. An asset being dragged to the scene, the label represents the 3D object.

The communication between GIFT and the tutoring application is defined in a real time assessment file as known as (DKF) which is appended to the external application. This file maps actions in the tutoring application triggered by messages to instructional strategies in GIFT. Since our purpose is to introduce GARAT, no additional assessment conditions were developed, instead, an existing condition assessment from GIFT was selected. Assessments were performed at the concept level via the StringMatchingCondition which defines concepts based on <key,value> sets, which trigger feedback responses based on the external application input as shown in Figure 7. The same configuration is used for both of the examples proposed in this work.

To summarize we can define the process of Authoring in the following steps:

- Create a Unity external application object.
- From the GARAT interface, click start server which runs an XMLRPC server and client instance on GIFT.
- Start Authoring Application on HoloLens. (Acquire 3d reconstruction, place anchors, etc.)
- Visualize the scene on GARAT, place objects and label them.

- Append a Real Time Assessment.
- Save the course

And the process of tutoring:

- In the HoloLens external application transforms are applied to gameobjects defined in GARAT.
- Messages sent to GIFT need to be defined via XMLRPC depending on users input.

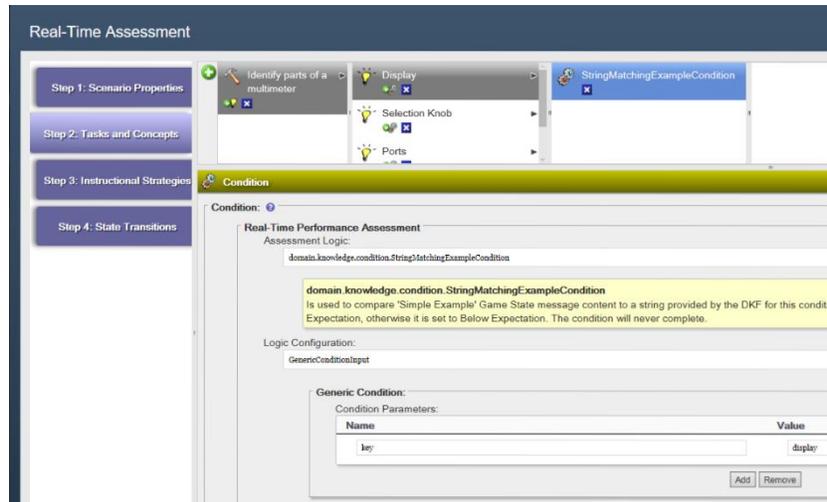


Figure 7. Real Time Assessment file for defining multimeter parts concepts.

Tutoring System to identify security leaks on a SCIF

The objective of this tutoring course is to brief a user on specific rules for handling classified information. As shown in Figure 1, a classified folder is left unattended on top of the desk and an unlabeled USB stick is left within the computer. For this specific problem, in pursuance of authoring an AR course, an awareness of the physical dimensions of the office is required. After a 3D scan has been performed on the room and sent to GARAT we proceed to place 3D objects accordingly in positions we expect the trainee to visualize them, an example of this placement is shown in Figure 8. The 3D objects are mapped to game objects in the HoloLens client application, however interaction events that will send messages to the GIFT server depend upon the client application specifics. The user is asked to “Identify risk threats in the office”. Gaze-tap on top of the elements is used to let GIFT know risk threats are being identified. The messages are mapped to a real time assessment file defined for the course through a StringMatchingCondition class. The feedback on HoloLens is displayed in a modal pop up window overlaid on screen space. The course ends when all risk threads have been identified.

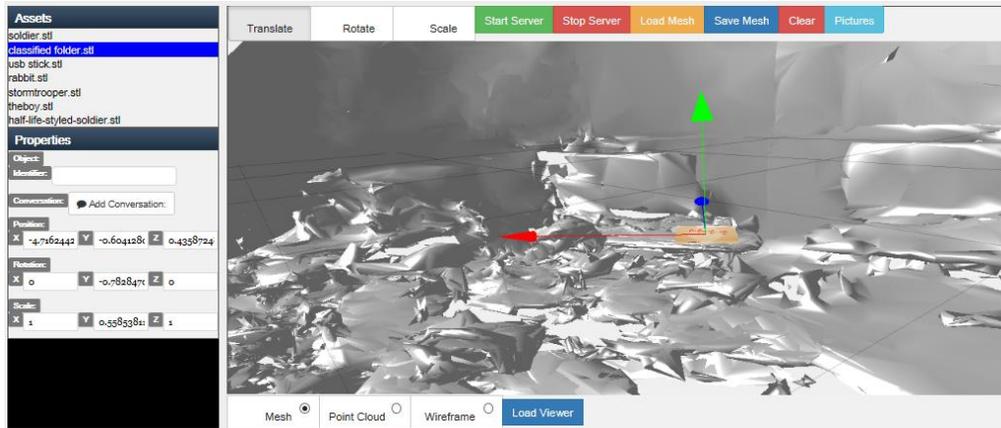


Figure 8. Applying transformations to the classified folder added to the scene mesh. Properties of the object are set on the left panel.

Tutoring System on the use of a Multimeter

Augmented Reality not only takes advantage of the spatial information (room geometry) but also can be used for object recognition. In this matter, we developed a course that augments information over a device, in this case a multimeter, to achieve some level of training. This example requires more development on the client due to the object recognition. Vuforia library allows to obtain a 3D mapping of objects with dimensions around 15 x 15 x 5 cm. This information can be fed into a HoloLens application and the object becomes trackable in HoloLens space. Messages are sent via the Unity interop to request information accordingly to the area of the device being gaze-tapped. In this way if the user gaze and tap on the selection knob, GIFT provides information about this part of the multimeter as can be seen in Figure 9. The assessment performance is defined in a Real Time Assessment file (see Figure 7). The information displayed over the tracked object is received as feedback from GIFT when the user gaze and tap on the corresponding part of the multimeter. The gaze and tap event sends a message back to GIFT with a key value indicating the instructional strategy to be triggered based on this input.

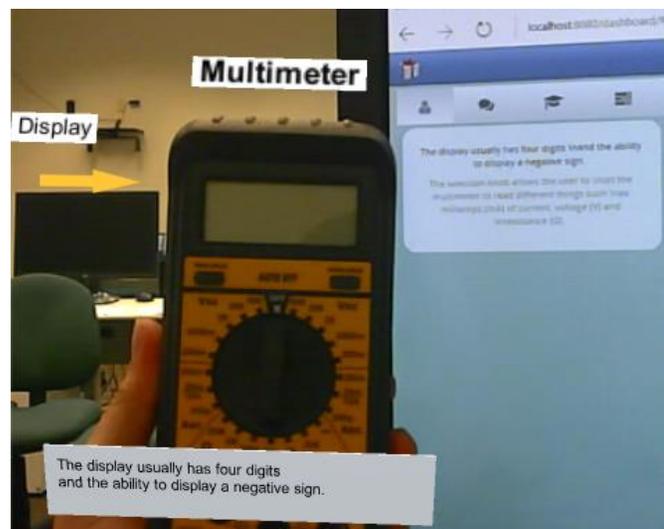


Figure 9. By gazing and tapping at the display, information displayed in the TUI is received in the HoloLens external application.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

There are many challenges that arise when developing training applications but the work can be simplified by extending the capabilities of existing tools. The development of a complete tutoring experience from GIFT represents a challenge due to the different capabilities, interaction techniques, physical tasks, etc that could be needed. However, in this work we aim to ease the pipeline introducing the GARAT tool. Leveraging most of GIFT capabilities directly on the interface pose a challenge, having a separated interface to define concept, tasks and assessment conditions could lead to jump back and forth between GARAT and the modal window. In the case of the device tutoring course a more natural interaction with the equipment is required e.g. identifying that the selection knob is placed on milliamps or voltage or selecting if the correct wire is connected to the right port. As done with the spatial awareness in GARAT an authoring tool can be implemented to ease this process.

This work contribution can be summarized as:

- An initial exploration in the use of GIFT as a generator of augmented reality tutoring courses.
- A tool for content generation of Augmented Reality scenarios that can be scaled to produce more complex behaviors and training scenarios inside GIFT.
- An XMLRPC server¹ implementation to connect Windows Universal Apps to GIFT.

The ability to connect to external platforms open the possibilities to use current or future head mounted displays that can provide better user experience. The architecture is built upon a modular architecture which can be reused across different external application platforms. HoloLens is a compact hardware which allows to have a rough 3D mapping of the world (coarse mesh), however, its internal algorithms are closed source code and it provides limited data, specifically RGB and depth information in real time. The tutoring experiences presented in this work were constrained to the HoloLens predefined interaction techniques. The GIFT user interface in some cases tend to hide some capabilities with the overuse of modal windows. Adding an interop requires some steps that can possibly be simplified. In future research, a system that requires minimum programming needs to be developed and tested with regular users.

The interface we have developed is a prototype that provides the first step toward the creation of advanced authoring tools which can easily merge intelligent tutoring systems with augmented reality. While shortcomings exist in the hardware and software chosen, we demonstrated potential work arounds or future solutions which will improve the system further. With each iteration developed, authoring tools such as GARAT will simplify and solve the obstacles faced in the creation of augmented reality training courses.

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¹ https://github.com/andnovar/xmlrpc-universal/tree/xmlrpc_server

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