

Supporting Modeling and Simulation Interoperability Standards within ESRI ArcGIS

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ABSTRACT: *Distributed simulations are widely used for training, system concept evaluation, and increasingly for operational uses such as embedded training, course of action analysis, mission planning, mission rehearsal, and predictive situational awareness. The Distributed Interactive Simulation (DIS) and High Level Architecture (HLA) are the DoD standard protocols used to link together distributed simulations. These simulations typically have requirements to visualize rapidly-updating, geographically-referenced data that is shared via DIS or HLA or TENA. The Commercial Joint Mapping Tool Kit (C/JMTK) acquisition program provides the underlying toolkit that will be deployed to support both legacy Mission Applications and new systems being developed throughout the DoD C4I Community. At the core of C/JMTK is the ESRI ArcGIS geographic information system. In order to effectively combine the simulation and operational environments, we need to provide seamless mechanisms to display 2D MOLE symbology in ArcMap and display 3D models in ArcGlobe that correspond to the simulated objects. In addition, these simulations may use geographic data analysis as part of implementing behaviors for computer-generated objects, requiring seamless access to the geo-database and geo-processing tools and the ability to publish these objects via DIS or HLA or TENA.*

In this paper, we discuss requirements and approaches for integrating DIS, HLA, and TENA into ArcGIS-based systems, to allow simulated entities to be rapidly displayed and manipulated. This will include a description of the approach used and the lessons learned while incorporating real-time updates into the ArcGIS product framework.

Introduction

“Train as you fight” is a standard mantra repeated by all the services. An ideal way to accomplish this is to use real equipment and real systems stimulated with simulated data while in the field rather than requiring soldiers to travel to costly simulation centers. If we focus on command and control training for an operational environment, the goal is to enable training embedded within the actual C4I system. In addition, as the compute power of these systems continues to increase and simulations become more and more sophisticated, we not only can take advantage of simulations for training but also to support course-of-action (COA) analysis and prediction. Finally, an additional objective is to address not only individual skills, but enable team training by leveraging distributed simulations.

Currently, the operational environment consists of a number of C4I systems, located either in vehicles or in command centers, connected via a variety of tactical data links (TADILs) that support several standards or distributed databases with several standard schemas. In addition, numerous efforts are underway to define interoperability between these stove-pipe systems via XML messaging or development of special purpose portals/gateways/adapters.

The simulation domain has its own set of interoperability standards including DIS, HLA, and TENA and has also resorted to the use of gateways to convert between them. However, the use of gateways adds latency, may represent a bottle neck or single point of failure, and introduces the potential for nuances to be lost in translation. In addition, if we try to bridge the operational and training environments by injecting simulated data into the live data transmission mechanisms, we run the risk of confusion between real and simulated objects. Ideally, we would like a method to support these simulation standards directly within operational systems so that the data can remain separate and the systems can control how the simulated data is managed.

A primary component of current and future C4I systems is the Commercial Joint Mapping Toolkit (C/JMTK). C/JMTK is a scalable, open architecture with open development environments, incorporating industry standards. The primary commercial component of C/JMTK is the ESRI geographic information system (GIS), ArcGIS. C/JMTK is essentially the adoption of the ArcGIS platform as the standard geospatial exploitation tool for DoD C4I systems.¹ Since C/JMTK is the foundation for C4I systems, providing the underlying data management and visualization capabilities, an approach towards enabling better synergy between the simulation and

operational environments is to seamlessly support DIS/HLA/TENA within ArcGIS.

GIS-Link Overview

MÄK developed GIS-Link to provide the underlying components to enable ESRI ArcGIS-based applications to connect to a simulation exercise and visualize real-time data. A primary design goal was to seamlessly integrate with the ArcGIS development paradigm. ArcGIS is based on a modular, scaleable, cross-platform architecture comprised of libraries of software components called ArcObjects. ArcObjects are platform-independent software components, written in C++, that provide services to support GIS applications, either on the desktop in the form of thick and thin clients or on a server for web and traditional client/server deployments. ArcObjects can be accessed via a choice of standard developer languages including COM, .NET, Java, and C++ on Windows, Linux, and Solaris computing platforms. In addition, higher-level GUI components are available as developer controls that simplify application development.

Using GIS-Link, simulated data can be visualized within ArcMap as rapidly updating symbology and within ArcGlobe as dynamic 3D models. For C4I system developers, GIS-Link is designed as a toolkit with the components comprised of underlying ArcObjects that easily integrate with other ArcGIS components. The overall goal is to supply developer building blocks that:

- Support HLA/DIS/TENA simulation interoperability standards
- Enable visualization of HLA/DIS/TENA-specific objects & interactions.
- Provide higher-level GUI components for viewing & configuring HLA/DIS/TENA-specific functionality.
- Are consistent with the existing ArcGIS COM-based framework to facilitate seamless integration.

GIS-Link is a suite of components that include:

- An extension for ArcMap (*Map-Link*),
- An extension for ArcGlobe (*Globe-Link*), and
- ArcObjects available for use with other ArcGIS Engine components.

Basically, GIS-Link is comprised of:

- ArcObjects that wrap the functionality of the MÄK VR-Link networking toolkit.²
- ArcObjects for GUI components and display capabilities.
- ArcMap and ArcGlobe extension toolbars.

GIS-Link Technical Architecture

GIS-Link is a suite of components that wrap the functionality of VR-Link and present the developer's interface as ArcObjects that seamlessly integrate with ArcObjects from other developer toolkits. In addition, GIS-Link follows the ESRI ArcGIS extension paradigm to enable functionality to be demonstrated within the ArcMap 2D desktop GIS and the ArcGlobe 3D viewer.

Map-Link

Map-Link is an ArcMap extension that enables users to access the underlying functionality of the ArcObjects, connect to a HLA/DIS/TENA exercise, and visualize associated objects and interactions. The functionality is presented as an ArcMap toolbar enabling a user to specify connection parameters, view details about Entity and Aggregate objects, visualize Entity and Aggregate objects as MILSTD 2525B symbology, and view Fire and Detonate interactions as animated sequences. Objects are managed as ArcMap layers, with the user having access to various automatic or manual mechanisms for specifying what is in each layer. By making use of a consistent layer management paradigm enables the users to manipulate the dynamic data just as they would manage terrain data layers, enabling users to turn layers on or off and to access instance information using the ArcMap Identify tool.

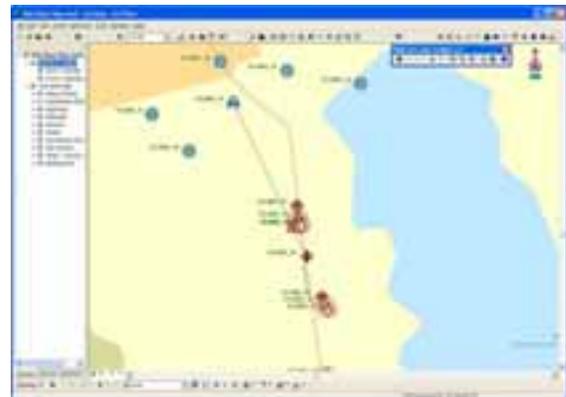


Figure 1: Screenshot of Map-Link extension within the ESRI ArcMap application.

Basic capabilities of the initial product release include the ability to:

- Connect to a DIS, HLA 1.3, HLA 1516, or TENA exercise and interactively close the connection and re-connect to a different exercise type.
- Define layers, either manually or automatically.
- Display objects or interactions, with the mapping of each to its visual representation being configurable by the user.
- Show dialogs to display
 - Entities by layer
 - Simulation-specific attributes
 - Entity-specific information
 - Aggregate-specific information
- Display fire and detonate interactions.
- Display target-to-shooter lines.
- Display real-time, dynamic entities and aggregates as ESRI MOLE symbology or images.
- Use ArcMap “identify” tool to access object details.
- Toggle on/off entity labels in a 2525B conformant manner.
- Configure the display update rate independent of the exercise connection drain rate.
- Display object heading and velocity vectors.

Beyond the initial version, the product roadmap calls for supporting more objects and interactions and additional visualization capabilities.

Globe-Link

Globe-Link is an ArcGlobe extension that enables users to access the underlying functionality of the ArcObjects, connect to a HLA/DIS/TENA exercise, and visualize associated objects and interactions as 3D models. Map-Link and Globe-Link share common code, so the capabilities to specify the exercise connection and display object details are identical. Globe-Link changes the visualization aspects to display the HLA/DIS/TENA objects and interactions in 3D within the ArcGlobe environment vs. 2D symbology on a map-based display.

Basic capabilities of the initial product release include the ability to:

- Connect to a DIS, HLA 1.3, HLA 1516, or TENA exercise and interactively close the

connection and re-connect to a different exercise type.

- Define layers, either manually or automatically.
- Display objects or interactions as OpenFlight models, with the mapping of each to its visual representation being configurable by the user.
- Show dialogs to display
 - Entities by layer
 - Simulation-specific attributes
 - Entity-specific information
 - Aggregate-specific information
- Display fire and detonate interactions as animated 3D sequences.
- Display target-to-shooter lines.
- Support ability to attach to individual objects in various modes including Compass and Mimic.



Figure 2: Screenshot of Globe-Link extension within the ESRI ArcGlobe application.

Beyond the initial version, the product roadmap calls for supporting more objects and interactions and additional visualization capabilities.

GIS-Link Toolkit

All functionality is provided to the developers as ArcObjects. In addition to the functionality demonstrated within the ArcMap and ArcGlobe extensions, developers also have the ability to create and publish objects and interactions to a DIS, HLA 1.3, HLA 1516, or TENA exercise. For the initial version, the functionality is accessible via a C++ interface, but because of the COM object paradigm, interfaces for other languages can easily be developed.

Lessons Learned

One of the primary lessons learned was the interpretation of what the GIS and Simulation

communities perceived as *real-time* updates. For the GIS community, the expectation was *seconds-per-update*, while the Simulation community expected *updates-per-second*. For a real-time simulation, it is not uncommon to update an object at 30 or 60 times per second and to do this for a large number of objects. However, for a GIS displaying temporal data, 1 update per second was considered extremely fast! Temporal data within a GIS is often stored in a database, so retrieval and display of data faster than those rates is probably unreasonable. Because of this fact, the visualization capabilities of ArcMap were not tuned to support extremely fast updates and exhibited “flashing” if a developer attempted to update dynamic data too quickly. To address this, ESRI developed an Accelerated Display extension which enabled rapidly updating MOLE symbology within ArcMap. Now, GIS-Link developers can make use of the new ESRI extension for rapidly updating displays or scale-back the display updates for “normal” display mode.

Use Cases for Combining Operational and Simulations Environments

There are a number of past and present examples where MÄK or others have tried to combine simulated and “real” systems to satisfy training needs. This section briefly introduces the examples, discusses each strategy for linking the environments, and discusses the benefits and limitations of each. These examples range from the use of simulated data to stimulate operational C4I systems to support training to a few thoughts on the Simulation-based Acquisition (SBA) process and how a seamless integration of the environments could help reduce cost and time. Although these examples do not necessarily use C/JMTK, ArcGIS, or GIS-Link, they do serve to exemplify likely future development scenarios.

FBCB2 Embedded Training

One example was a PEO-STRI-sponsored project, where Stottler-Henke developed an Intelligent Tutoring System (ITS) prototype to demonstrate the ability to teach tactical decision making and tactical use of Force XXI Battle Command Brigade and Below (FBCB2). For the project, the goal was to present course material and examples to a trainee then test the commander in tactical situations simulated by the OneSAF Testbed (OTB) computer-generated forces (CGF) application and display the simulated common operational picture within FBCB2. To accomplish this, Stottler-Henke used the Situational Awareness Tactical Internet Data Server (SATIDS) as a gateway to convert

between DIS (OTB) & Variable Message Format (VMF) (FBCB2).³ Their approach was a common one to use a gateway to convert simulated objects and interactions, generated in DIS by OTB into corresponding operational VMF messages. However, the use of any gateway adds latency and the potential for translation differences.

FBCB2 Stimulation

A second example is another PEO-STRI-sponsored prototype also focused on training on the use of FBCB2. The project was a collaboration between Lockheed Martin, SAIC, and MÄK. The approach was to use a MÄK-developed video game, Spearhead, to stimulate FBCB2. Spearhead was a DIS-compliant tank simulation, where a trainee could play the roles of driver, gunner, and commander, providing a first-person view from the tank on one display. On a second display, the trainee displayed FBCB2. Trainees could input and follow a plan, drive the tank and engage the enemy. The approach used was also to utilize SATIDS as a gateway to convert simulated objects and interactions, generated in DIS by Spearhead, into corresponding operational VMF messages to stimulate C2PC.⁴ Once again, the use of any gateway adds latency and the potential for translation differences. In addition, SATIDS required the generation of hard-coded Unit Reference Numbers (URNs) to map to DIS entities so that the translation could occur.

C2PC Stimulation

A recent example was a PM-TRASYS- and TECOM-sponsored project where MÄK used the USMC Tactical Decision-making Simulation, MAGTF-XXI-XXI to stimulate the Command and Control Personal Computer (C2PC) C4I system. This combined system is used at both the USMC Marine Expeditionary School in Quantico, VA and at the School of Infantry-East in Camp Lejeune, NC to support multi-player, staff-level command and control training. The trainees perform planning in C2PC and the generated tactical graphics are exported to MAGTF-XXI. Next, a corresponding simulated scenario is executed in MAGTF-XXI, with the resulting units visualized in C2PC. SPOTREPs and SITREPs generated by the simulated forces within MAGTF-XXI create the symbology visualized on C2PC. In order to stimulate C2PC, we used a custom gateway, based on MÄK VR-Exchange, to convert between HLA (MAGTF-XXI) and objects created using the C2PC Injector SDK (C2PC). Because of this approach, the application suffered numerous performance issues due to the

implementation approach used in the C2PC SDK and required updated for each new version of C2PC as the SDK kept changing.

Navy DD(X)

As the DoD transitions towards a SBA process for the next-generation vehicles and systems, an obvious goal will be to reuse simulation components generated during the early stages as the basis for eventual training components during fielding. A recent example of this desire was witnessed by MÄK in our interactions with Raytheon and the Navy DD(X) program.

Raytheon is the prime mission systems integrator and has been using MÄK simulation products to simulate/stimulate mission system components as part of their detailed design and system integration, test, verification and validation. However, recently Raytheon's training division approached MÄK to discuss the best methods to transition these initial simulation models for use in an eventual embedded training system. They recognized the value of not "reinventing the wheel" and creating a new training system from scratch, when many of the models already existed.

References

1. For more information on C/JMTK or ArcGIS, see <http://www.cjmtk.com> and <http://www.esri.com>.
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3. <http://www.stottlerhenke.com/papers/IITSEC-02-FBCB2.pdf>
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