An Approach to Integrating Modeling & Simulation Interoperability

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ABSTRACT: *Distributed simulations are widely used for training, concept evaluation, and increasingly for operational uses such as embedded training, course-of-action analysis, mission planning/rehearsal, and predictive situational awareness. The Distributed Interactive Simulation (DIS), High Level Architecture (HLA), and Test and Training Enabling Architecture (TENA) 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, HLA or TENA. This means that we need to provide seamless mechanisms to display 2D symbology in ArcMap or 3D models in ArcGlobe that correspond to simulated objects.*

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.

1. Introduction

MÄK Technologies has embarked on an R&D initiative, referred to as *GIS-enabled Modeling and Simulation (GEMS)*, to explore how to utilize the functionality of a GIS as a core component of the simulation infrastructure. This makes sense because simulations need the ability to:

- Visualize terrain in 2D & 3D.
- Analyze and reason about terrain.
- Do this in distributed manner.

ESRI ArcGIS is the leading GIS software suite in the industry. ArcGIS can provide much of necessary functionality, but currently has the following limitations:

- Distribution of data not *real* real-time.
- Display updates can only support *seconds per update* not *updates per second.*
- Does not support simulation interoperability standards HLA, DIS or TENA

Another driving factor into looking at GIS technology is the desire to merge C4I and simulation capabilities. A primary component of current and future US C4I systems is the Commercial Joint Mapping Toolkit (CJMTK). CJMTK is a scalable, open architecture with open development environments, incorporating industry standards. The primary commercial component of CJMTK is ESRI ArcGIS. CJMTK is essentially the adoption of the ArcGIS platform as the standard geospatial exploitation tool for DoD C4I systems.[1] Since CJMTK is the foundation for C4I systems, providing the underlying data management and visualization capabilities, an approach towards enabling better integration between the simulation and operational environments is to seamlessly support simulation interoperability standards within ArcGIS.

Why do we want to merge C4I and simulations anyway? "Train as you fight" is now a common statement repeated across the world. An ideal way to accomplish this is to use real equipment and real systems using 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

[1] http://www.cjmtk.com

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). These systems support several standards or distributed databases with several standard or proprietary 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.

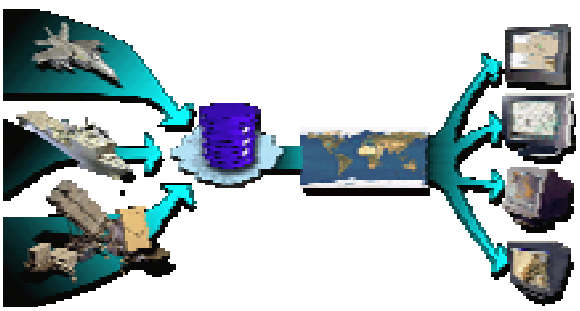

Figure 1: Typical C4I architecture with sensor feeds generating tracks stored in a DB, which creates a global Common Operational Picture (COP), which can then be displayed in a variety of ways.

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 *bottleneck 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.

In addition, a Danish company, Systematic, has created a commercially-available C4I system. Systematic's SitaWare[2] provides a command and control framework based on ArcGIS and C2IEDM (Command and Control Information Exchange Data Model)[3], which can be used as a comprehensive C2 system or it can be integrated as part of a custom solution. Since SitaWare also uses ArcGIS, any approach used for CJMTK could also benefit SitaWare, enabling the creation of an out-of-the-box solution for C2 with embedded training, analysis, and prediction.

2. GIS-to-SIM Overview

MÄK developed GIS-to-SIM 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-to-SIM, simulated data can be visualized within ArcMap as rapidly updating symbology and within ArcGlobe as dynamic 3D models. For C4I system developers, GIS-to-SIM 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.

[2] http://www.systematic.dk/UK/Products/SitaWare

[3] http://www.mip-site.org

- Are consistent with the existing ArcGIS COM-based framework to facilitate seamless integration.

GIS-to-SIM is a suite of components that include:

- An extension for ArcMap,
- An extension for ArcGlobe, and
- ArcObjects available for use with other ArcGIS Engine components.

3. GIS-to-SIM Technical Architecture

GIS-to-SIM is a suite of components that wrap the functionality of the MÄK VR-Link network toolkit[4] and present a developer's interface as ArcObjects that seamlessly integrate with ArcObjects from the ArcGIS Engine. In addition, GIS-to-SIM follows the ESRI ArcGIS extension paradigm to enable functionality to be demonstrated within the ArcMap 2D desktop GIS and the ArcGlobe 3D viewer.

3.1 GIS-to-SIM for ArcMap

GIS-to-SIM includes 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. 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.

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

- Connect to a DIS, HLA 1.3, or HLA 1516 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 hierarchies
  - 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 unit heading and velocity vectors.

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

Figure 2: Screenshot of the GIS-to-SIM extension for the ESRI ArcMap application.

3.2 GIS-to-SIM for ArcGlobe

GIS-to-SIM also includes an ArcGlobe extension that enables users to access the underlying functionality of the ArcObjects, connect to a

[4] http://www.mak.com

HLA/DIS/TENA exercise, and visualize associated objects and interactions as 3D models. Both extensions share common code, so the capabilities to specify the exercise connection and display object details are identical. The ArcGlobe extension changes the visualization aspects to display the HLA/DIS/TENA objects in 3D within the ArcGlobe environment vs. 2D symbology on a map-based display.

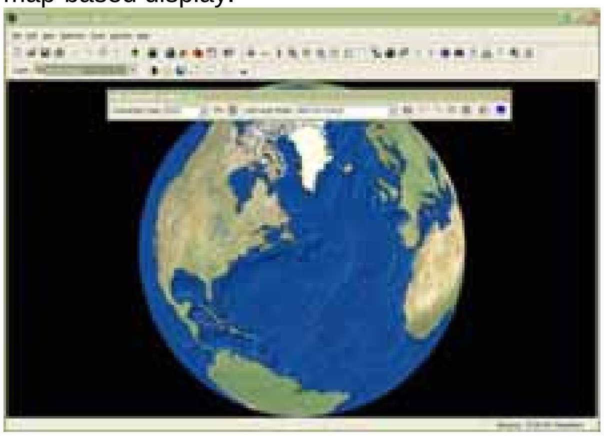

Figure 3: Screenshot of the GIS-to-SIM extension for the ESRI ArcGlobe application.

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

- Connect to a DIS, HLA 1.3, HLA 1516 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
    - o Entities by layer
    - o Simulation-specific attributes
    - o Entity-specific information
    - o Aggregate hierarchies
    - o Aggregate-specific information
- Display target-to-shooter lines.
- Support ability to attach to individual objects in various modes including Compass and Mimic.

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

3.3 GIS-to-SIM 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.

3. Use Cases

There a variety of ways that GIS-to-SIM could be used to support embedded training, COA analysis, or prediction of possible future events. GIS-to-SIM seamlessly integrates with other ArcObjects, which are the developer components that make up the ESRI application programming interface. Therefore, any ArcGIS-based application can easily incorporate GIS-to-SIM functionality to access simulated exercise feeds and visualize the resulting objects.

In order to implement an embedded training capability within an ArcGIS-based (e.g. CJMTK-based) C4I system, the system developer might define a "training" mode, where operational feeds are turned off and simulated exercises are accessed instead. The developer could implement a specialized training GUI that substitutes for the human-to-human voice communication that exists in a real operational environment, providing an interactive method to task simulated units. The developer could also implement a more video game-like interface (e.g. animations, sound effects, etc.) for the training mode to create a more engaging environment. Finally, the developer could use similar game-like techniques and the ability to visualize non-visual data (sensor volumes, NBC clouds, target-to-shooter lines, etc.) to create an engaging after-action review (AAR) capability to reinforce desired training objects.

For COA analysis, or predictive situational awareness capabilities, a developer could use the current COP, tactical plans, and intelligence estimates to dynamically generate a starting point for a simulated exercise. The simulation could then be run and interactively visualized (maybe as separate layers) and compared to the plan or outcomes analyzed. Based on those results, tactical plans could be updated or units retasked to address any potential risks identified during the simulation.

4. Vision of the Future

As C4I development moves towards fully-embedded training as an organic component of each system, the line between interfaces for operational and simulated exercises could be blurred. Instead of training-specific GUIs or extra visualization capabilities needed for AAR, common interfaces could be developed and used for either operational or training purposes, depending on the mode. For example, if C4I systems adopt formatted message types like the Coalition Battle Management Language (CBML)[5], which provides an unambiguous language for communicating plans and orders, GUIs could be developed to input orders that could be sent to live participants as well as simulated units. Therefore, the same interface could be used with the only difference being switching to "training" mode instead of the normal operational mode.

Author Biographies

BRIAN SPAULDING is the Director of R&D at MÄK Technologies, responsible for management of all simulation-based, R&D contracts. Some of these include the TEC-sponsored research on merging M&S and operational environments, DARPA-sponsored DARWARS program, and the tactical decision-making simulation development efforts including Battle Command, MAGTF-XXI, and Game-Link.

JORGE MORALES is a Senior Engineer at MÄK Technologies and is the primary software developer of the GIS-to-SIM product.

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5 http://www.movesinstitute.org/~blais/Documents/05F-SIW-041%20presentation.pdf